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Page 78, line 32, for "Persio" read "Persis."
Page 78, line 33, for "Turcio dicitus" read "Turcis dicitur."
Page 79, line 2, for "Lugds. Bat." read "Lugd-Bat."
Page 81, line 7, for "cano" read "çana."
Page 81, line 9, for "can or canai" read "çan or çanai."
Page 81, lines 20 and 22, for "sarso" read "sarsõ."
Page 222, line 32, for "H. H. Wright" read "A. H. Wright."

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CONTENTS

No. 1. JANUARY–FEBRUARY.

PAGE.
Khankhoje, P. S.—Some Factors which Influence the Water Requirements of Plants. (Fig. 1.) 1
Salmon, Cecil.—Sterile Florets in Wheat and Other Cereals. (Pls. I–II.) 24
Scofield, C. S.—Community Growing of Crop Varieties 31
Giles, P. L.—On the Plans of Fertilizer Experiments. (Fig. 2.) 36

Briefer Articles.

Farrell, F. D.—Basing Alfalfa Yields on Green Weights.......... 42

Agronomic Affairs.

A Thought for the New Year 45
Special Meeting at Dallas, Texas 46
Membership Changes 47
Coming Events 48
Local Sections 48

No. 2. MARCH–APRIL.

Stewart, Robert, and C. H. **Hirst.**—Nitrogen and Organic Matter in Dry-farm Soils 49
Bailey, C. H.—The Composition and Quality of Mexican Wheats and Wheat Flours 57
Harris, Frank S.—The Effect of Soil Moisture, Plant Food and Age on the Ratio of Tops to Roots in Plants 65
Piper, C. V.—The Name of the Soy Bean: A Chapter in its Botanical History 75
Cunningham, C. C.—A New Method of Growing Corn. (Figs. 3–4.).... 84

Agronomic Affairs.

Agronomy and Botany 89
Membership Changes 90
Notes and News 91
Coming Events 96
Local Sections 96

No. 3. MAY–JUNE.

Love, H. H.—Relation of Yield of Straw and Grain in Oats. (Figs. 5–11.) 97
Schreiner, Oswald, and **Skinner**, J. J.—Field Tests with a Toxic Soil Constituent; Salicylic Aldehyde. (Pls. III–IV.) 108
McKee, Roland.—Moisture as a Factor of Error in Determining Forage Yields. (Introduction by C. V. Piper) 113
Warburton, C. W.—Notes on Oats for the Southern States 118

537040

PAGE.
BRIEFER ARTICLES.
WIANCKO, A. T.—Use and Management of Check Plats in Soil Fertility Investigations 122
GRANTHAM, A. E.—The Effect of Rate of Seeding on Competition in Wheat Varieties 124
SALMON, CECIL.—Check Plats a Source of Error in Varietal Tests 128
TUCKER, GEORGE M.—Uniformity in Experimental Agronomic Work.. 131
AGRONOMIC AFFAIRS.
Expansion of Agricultural Extension 133
Do Members Want their Engravings? 134
Membership Changes 135
Notes and News 136
Coming Events 137
Local Sections 138

NOS. 4 AND 5. JULY–OCTOBER.

BOUYOUCOS, GEO. J.—Some Observations on Agricultural Conditions in Germany, France and England 139
MCCOOL, M. M.—Some Unusual Soils that Occur in Oregon 159
FRY, WILLIAM H.—Petrography of Various Soils Derived from Volcanic Ejecta 164
CLARK, J. ALLEN.—A Statistical Study of Barley at Dickinson (N. D.) Substation. (Figs. 12–18) 171
OLMSTEAD, L. B.—Some Applications of the Method of Least Squares to Agricultural Experiments. (Fig. 19) 190
KELLERMAN, KARL F., and WRIGHT, R. CLAUDE.—Mutual Influence of Certain Crops in Relation to Nitrogen. (Figs. (20–23) 204
WESTGATE, J. M., and OAKLEY, R. A.—Percentage of Protein in Nonlegumes and Legumes when Grown Alone and in Association in Field Mixtures 210
BRIEFER ARTICLES.
BAILEY, C. H.—The Composition and Quality of Wheat Grown in Mixtures with Oats 215
SPRAGG, FRANK A.—Winter Barley in Michigan 217
AGRONOMIC AFFAIRS.
The Theory of Factors in Crop Production 218
Doctorates Conferred in 1914 220
Notes and News 221
New Books 224
Membership Changes 225
Coming Events 226

NO. 6. NOVEMBER–DECEMBER.

PIPER, C. V.—Fundamental Principles in Agronomy. (Presidential Address) 227
STEWART, ROBERT, and PETERSON, WILLIAM.—The Origin of the "Nitre Spots" in Certain Western Soils 241

PAGE.
CALL, L. E.—The Effect of Different Methods of Preparing a Seed Bed for Winter Wheat upon Yield, Soil Moisture, and Nitrates. (Figs. 24–25, Pls. V–VI) 249
AGRONOMIC AFFAIRS.
In Passing 260
Notes and News 261
New Books 262
Report of the Secretary for 1914 264
Funds Collected 264
Meetings 265
Membership 265
Address List of Members 266
Journal and Proceedings 275
Minutes of the Annual Meeting 276
Seven-year Summary 278
Report of the Treasurer 282
Reports of the Committees 283
Executive 283
Soil Classification and Mapping 284
Standardization of Field Experiments 289
Agronomic Terminology 289
LOCAL SECTIONS 290
INDEX 291

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VOL. 6 JANUARY–FEBRUARY, 1914 NO. 1

SOME FACTORS WHICH INFLUENCE THE WATER REQUIREMENTS OF PLANTS.

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INTRODUCTION.

It is a well-known fact that water is essential for plant growth. but the exact rôle of water in plant growth is not yet fully understood, nor is the practice of its application yet perfected. Hence, the problem of "Water Requirements of Plants" presents a twofold significance—theoretical and economical (practical). From the scientific viewpoint alone the thorough investigation of this problem has a great value but the limited supply of water for the crops in irrigated and arid regions is forcing investigators to take this subject for research at their earliest convenience.

A few investigators have realized the significance of the subject and conducted many experiments along this line. They have contributed a great deal toward the furtherance of knowledge of this subject but it is unfortunate that these men are few and that their results show a wide variation and in some cases contradiction, as will be noted in Table I.

TABLE I.—*Showing a Wide Variation in the Number of Pounds of Water Required by Different Field Crops to Produce a Pound of Dry Matter.*

Crop.[1]	Lawes and Gilbert.[2]	Hellriegel.[2]	Sorauer.[2]	Wollny.[2]	King.[2]	Widtsoe.
Wheat	225	338	459	....	....	1,048
Oats	....	376	569	665	385	....

[1] Lyon and Fippin, Soils, p. 134.

[2] Widtsoe, J. A., Dry Farming, pp. 14–16.

As examples of contradiction: "By admitting live steam into our plant house on bright sunny days, keeping the air highly saturated, we have found corn to lose nearly as much moisture as in the drier condition of the air with the sun also shining"[3] and "We see that about twice as much water is required to give a unit of dry weight in the dry greenhouse as in the humid."[4] This statement also is made for the corn plant.

Statements like these are confusing, but, if the environment under which the experiments were performed and the methods used be taken into consideration, the record of these statements creates an interest in further investigations and so more light is thrown on the subject by new experiments. The future is always profited by past experience.

Such results always show one fact clearly. There must be several factors which influence the water requirements of plants. Otherwise the results would have been somewhat closer in accord.

The interest in the subject is comparatively new and therefore it is not surprising to find very few experiments that have been conducted to investigate the factors which influence the water requirements of plants. The time has come to know something more definite about these factors if an accurate knowledge of the subject is desired. On account of the "irregularities" in the results of transpiration experiments with plants, the suggestion has been made to investigate the subject "more thoroughly."[5]

In experiments with duty of water and transpiration the factors which are commonly supposed to influence transpiration are as follows:[6] "relative humidity, temperature, air currents, direct sunlight, strength of plant food solution in the soil, mechanical vibration, age of plant, kind of crop, the vigor of growth, root system, and[7] chemical nature of soil solution." For the systematic study of these factors some good and useful suggestions are made.[8]

The Washington State Agricultural Experiment Station, being located in the heart of the dry-farming country, was naturally interested in the problem of the water requirements of crops. A series of experiments was carried on under the direction of Professor C. C. Thom to determine the water requirements of the popular crops of the Palouse country. The want of a detailed knowledge of the factors influencing the water requirements of crops was very soon keenly felt by Professor Thom and a number of experiments were suggested by him and his assistant, Mr. H. F. Holtz. The work outlined in this paper is the result of those suggestions.

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[3] King, F. H., Physics of Agriculture, p. 145.

[4] Montgomery, E. G., Water Requirements of Crops, Proc. Am. Soc. Agron., 3: 276, (1911) 1912.

[5] Harris, F. S., Long versus Short Periods of Transpiration in Plants used as Indicators of Soil Fertility, Proc. Am. Soc. Agron., 2: 102, (1910) 1911.

[6] Widtsoe, J. A., Dry Farming, pp. 175–179.

[7] Bouyoucos, George J., Transpiration of Wheat Seedlings as Affected by Soils, by Solutions of Different Densities, and by Various Chemical Compounds, Proc. Am. Soc. Agron., 3: 131, (1911) 1912.

[8] Livingston, B. E., A Schematic Representation of the Water Relations of Plants, A Pedagogical Suggestion, Plant World, 15: 214, 1912.

Methods Used in the Experiments.

Experiments were carried on in the greenhouse and complete records of humidity and temperature kept.

Two-gallon glazed earthenware jars were used as receptacles for the medium in which to grow the plants; in one series this medium was pure quartz sand; in the other it was ordinary Palouse soil. Pots with pure sand were watered with the nutrient solution and those with the Palouse soil were watered with faucet water.

Preparing the Jars of Sand for Planting.

At the bottom of each two-gallon jar a three-inch, conical, porous flower-pot was inverted and placed in the center. A glass tube which was used for adding the solution was put through the hole in the bottom of the flower pot. This tube was one fourth of an inch in diameter and twelve inches long and rested on the bottom of the jar. Twenty-five pounds of pure quartz sand were poured into the jar. The diameter of the particles of sand was 1.5 mm. and its chemical analysis was as follows: pure SiO_2 99.88 percent, iron and aluminum .12 percent. The sand was slightly packed and the surface leveled before planting and sealing the jars.

Planting and Sealing of the Jars.

There was a slight difference in the order of procedure in the two experiments, in 1911 and 1912. In the former experiments the solution was added through the glass tube after paraffining; then three small holes were bored through the paraffine into which the germinated seedlings were transplanted. But in this method, the moisture in the quartz soil being unevenly distributed and some roots of the seedlings being injured while transplanting, many of them died though they were watered with distilled water in order to establish a good stand. To avoid this trouble, in 1912, the desired quantity of solution was added to the sand without disturbing the level of the surface. In order to insure germination, two kernels were planted in each of three equidistant holes half an inch deep in the sand of each jar and the surface was covered with a thick layer of papers in order to check the evaporation. After germination, three healthy plants were retained and the rest pulled out. The amount of moisture lost in the period of germination was calculated and replaced with distilled water. To protect the seedlings from injury by the warm wax in sealing, a paper tube of about one fourth inch diameter and one and one half inches in length was placed around each plant. A small glass tube, three to four inches long, was placed in one side of the surface for good aeration in the pot. Then the pots were sealed with a uniform layer of warm paraffin wax. When the wax was cooled, one pound of pure quartz sand mulch about a half inch deep was poured on the surface of the paraffin layer. Two blanks sealed with this method were tested in the greenhouse and under out-door conditions for some months. The loss of water by evaporation was not noticeable. This method of wetting the sand, then planting and sealing the jar gave the best results of all the methods that have been tried at the Washington Experiment Station.

Cultural Medium.

The formula for the food solution was taken from Detmer's Plant Physiology.[9] This formula is as follows:

	Gram.
Distilled water	1,000.00
Calcium nitrate ($Ca(NO_3)_2$)	1.00
Potassium chloride (KCl)	.25
Magnesium sulphate ($MgSO_4$)	.25
Potassium phosphate (KH_2PO_4)	.25
Ferric chloride solution	a few drops.

The formula used in this work was modified from the above as follows:

Distilled water	1,000.00 c.c.
$Ca(NO_3)_2$	1.00 gr.
NaCl	.25 gr.
$MgSO_4$	.25 gr.
KH_2PO_4	.25 gr.
Ferric chloride solution	a few drops.

The percentage composition of the inorganic salts of a wheat plant in the Palouse country is more nearly in accord with this formula than any other.

---

[9] Detmer, Practical Plant Physiology, p. 2 (ed. 2, trans. by S. A. Moor).

The strengths of solutions used were as follows: In the year of 1911: ${}^1/_5$, ${}^1/_{10}$, ${}^1/_{25}$, ${}^1/_{50}$, ${}^1/_{100}$, and ${}^1/_{250}$ of one percent. In the year 1912: ${}^1/_3$, ${}^1/_5$, ${}^1/_{10}$, ${}^1/_{15}$, ${}^1/_{20}$, ${}^1/_{30}$, ${}^1/_{60}$, ${}^1/_{80}$, and ${}^1/_{100}$ of one percent.

In the year 1911 three jars and in 1912 two jars of each series were taken. Fifteen percent of moisture or seventy-five percent of water-holding capacity was maintained in all the experiments at different strengths and on the effect of the age of plants. A tenth percent solution was found to be the best for plant growth and therefore this strength or percentage was used in those experiments wherein the effect of the different ages of plants and the different percentages of soil moisture was determined. In the soil moisture work eight percent and sixteen percent of soil moisture were maintained. Four jars were used in each of the moisture series. Only three pots were used in each series of the water requirements at different ages of plant growth and the plants were harvested at about forty-day intervals. There were only three stages of growth taken.

In addition to the series of experiments on the effect of different culture solutions similar experiments were conducted under different conditions as to temperature and atmospheric humidity. One tenth of one percent was the only solution used but in other respects the treatment given to these jars was the same as that given in the jars in the first experiment.

Use of Drinking Glasses for Small Pot Experiments.

In order to determine the effect of small pots on water requirements, ordinary drinking glasses were used as soil receptacles and different strengths of solution tried. Glasses were sealed with paraffin. There was one plant in each glass.

All the above experiments were conducted in the greenhouse and a record was kept of the temperature and the humidity. The total weight of the jar, soil, and solution added was known at the beginning of the experiment. All the pots were weighed every week and the loss in weight was taken as the amount of transpiration. This loss was replaced immediately. After two months of plant growth the loss was so great that the plants were showing signs of wilting and therefore were watered twice a week after that time.

Method of Preparing the Jars in which the Palouse Soil was Used.

The same size of jars was used in this series as in the culture solution series. The moisture was maintained at ten and twenty percent respectively. The planting was similar in all respects to that in the culture solution experiments. In order to maintain a natural condition of the soil these jars were not sealed but a heavy mulch of sand about an inch and a half deep was put on the surface in order to check evaporation from the soil. Ordinary faucet water was added through a glass tube as in the case of the culture solution experiments.

Jars were weighed every week as in the other experiments. The loss in the weight minus the evaporation through the check jars was taken as the amount of water transpired. In the experiments to determine the water requirements at different ages of plant growth in the Palouse soil the plants were harvested at the same time as those in the culture-solution experiment.

Good healthy seed of the same variety and uniform quality was used in all experiments in order to eliminate different influences due to inherent individual variation.

Harvesting.

Jars were weighed just before harvesting. The plants were cut near the surface of the soil with a knife and immediately weighed. Then the roots were separated from the soil by the use of large amounts of water, after which they were dried separately in an electric drying oven at 110° F. for about eight hours and weighed again. It was found practically impossible to wash all the sand out and therefore the roots were burned and the ash was dissolved in hot water. Sand was separated from the ash by decantation process and weights of ash and sand were determined. The weight of sand was subtracted from the first weight of the dry matter. In this way the accurate weight of the total dry matter of stalks and roots was determined.

THE KIND OF CROP AS A FACTOR INFLUENCING THE WATER REQUIREMENT.

These experiments were carried on in two-gallon jars, using the Palouse soil as a medium. The jars were all kept under the same out-of-door conditions.

Only two common crops, namely, wheat and oats were used. The average from different pots shows that wheat requires less water per unit of dry weight than does oats.

While working with the same crop sometimes reverse results are obtained. A number of jars were prepared just as above but for a different purpose and arranged with the jars of that experiment. All

TABLE 2.—*Showing the Kind of Crop as a Factor Influencing Water Requirements of Crops (Weights in Grams).*

Kind of Crop.	Jar No.	Dry Matter Produced.	Total Water Used.	Water Lost by Check.	Water Used by Plants.	Water per Gram of Dry Weight.	Average.
Wheat......	1	8.8143	4,090	884	3,206	363	....
Wheat......	2	6.7268	3,400	884	2,514	374	....
Wheat......	3	8.4018	4,090	884	3,206	381	372
Oats........	1	4.7136	2,830	855	1,945	413	....
Oats........	2	3.6507	2,830	855	1,945	533	....
Oats........	3	3.4024	2,560	855	1,705	502	482

other conditions were similar. The wheat in these jars required 408 grams of water per unit of dry weight and the oats 369 grams of water per unit. In this case the wheat required slightly more water than the oats. Therefore, the generalization that oats take more water than wheat, from the results as stated in Table 2, or vice versa from the other example will be misleading. One fact is clear

TABLE 3.—*Showing the Kind of Crop as a Factor Influencing the Water Requirement of Plants. Summary of the Results Obtained by Different Investigators (Weights in Grams).*

Kind of Crop.	Thom & Holtz,[10] Pot Expts., U. S. A.	Thom & Holtz,[11] Field Expts.	King,[12] Pot Expts., U. S. A.	Widtsoe,[13] Pot Expts., U. S. A.	Lawes,[14] Pot Expts., England.	Hellriegel,[14] Pot Expts., Germany.	Wollny,[14] Pot Expts., Germany.	Sorauer,[14] Germany.	Leather,[14] Pot Expts., India.	
Alfalfa......	414	......	......	......	......	......	......	......	......	......
Barley......	294	289	388.48	......	257	..	774	431	680	480
Field bean ..	444	262	......	......	209	282	......	......	......	......
Soja bean...	408	......	......	......	......	......	......	......	......	......
Sugar beets .	304	321	......	630	......	......	......	......	......	......
Cabbage....	398	......	......	......	......	......	......	......	......	......
Carrots.....	297	176	......	......	......	......	......	......	......	......
Red clover..	448	......	564.43	......	269	310	......	......	......	......
Corn.......	290	272	309.20	589	......	......	233	......	450	330
Oats.......	345	......	513.52	......	......	376	665	569	860	550
Onions.....	235	262	......	......	......	......	......	......	......	......
Peas.......	444	......	477.37	1,118	259	273	416	......	830	530
Potatoes....	167	335	......	......	......	......	......	......	......	......
Sorghum....	230	......	......	......	......	......	......	......	400	400
Timothy....	315	......	......	......	......	......	......	......	......	......
Tomatoes...	350	......	......	......	......	......	......	......	886	550
Wheat......	450	323	......	1,048	247	338	......	459	......	......
Wheat (durum)...	......	293	......	......	......	......	......	......	......	......

[10] Thom, C. C., Unpublished experiments, Wash. Expt. Sta.

[11] Thom and Holtz, Unpublished experiments at the Wash. Expt. Sta., 1911–1912.

[12] King, F. H., Wisconsin Experiment Station, Annual Report, 1892, p. 98.

[13] Widtsoe, J. A., Dry Farming, pp. 14–15.

[14] Leather, J. W., Water Requirements of Crops in India, Mem. Dept. Agric. in India, Chem. Ser., Vol. I (Nos. 8–10).

from the results given above: that with the same methods and under the same conditions the amount of water required for the different crops is different and the variation for the same crop generally is within certain limits. In table 2 the limit for wheat is from 363 to 381 grams of water and for oats from 413 to 533 grams.

The work of various investigators also substantiates the above statement, as will be seen from Table 3.

In Table 3 the results of the experiments of Hellrigel, Sorauer, and Leather show that a greater amount of water is required to produce a unit of dry matter in oats than in wheat. Excepting a few results that have very wide variation, it seems that wheat has a range of about 250 to 500 grams and oats of 350 to 700 grams.

STRENGTH OF THE SOIL SOLUTION AS A FACTOR INFLUENCING WATER REQUIREMENTS OF CROPS.

The plants in these experiments were grown in two-gallon sealed jars, in duplicate series, using the pure quartz sand as a soil medium and were watered with the following strengths of the nutrient solutions: one hundredth, one eightieth, one sixtieth, one thirtieth, one twentieth, one fifteenth, one tenth, one fifth, and one third of one percent. The results are shown in Table 4.

In this series of experiments the germination of wheat was very

TABLE 4.—*Showing the Influence of the Strength of Nutrient Solution on the Water Requirements of Full-grown Wheat Plants Grown in Two-gallon Jars, in Duplicate Series.*

Strength of Solution Used, in Fractions of One Percent.	No. of Jar.	Total Amt. of Dry Mat. (Including Roots) Produced.	Total Grams Water Transpired.	Water per Gram of Dry Matter.	Average of All Jars with Same Strength of Solution.
		grams.	*grams.*	*grams.*	
1/100	1	2.7552	1,675	608	....
1/100	2	1.7898	1,135	634	621
1/80	1	2.6570	1,600	603	....
1/80	2	3.1556	1,915	608	605
1/60	1	3.0012	1,525	509	....
1/60	2	4.0706	2,035	501	505
1/30	1	10.6126	5,160	386	....
1/30	2	7.5204	2,240	298	392
1/20	1	14.5640	5,710	392	....
1/20	2	15.3060	5,620	367	378
1/15	1	21.6446	7,660	354	....
1/15	2	14.0132	4,210	300	327
1/10	1	42.1809	11,600	275	....
1/10	2	38.2960	9,580	250	....
1/10	3	40.0733	10,380	259	261
1/5	1	19.9726	4,635	332	....
1/5	2	11.2193	2,735	244	238
1/3	1	16.3477	3,435	210	210

rapid in the weak solutions but in the stronger solutions it was very slow. For the first two months of the plant growth in the hundredth, eightieth, and sixtieth percent solutions the growth of the young seedlings was very rapid; in the thirtieth, twentieth, fifteenth, and tenth percent concentrations the growth of the seedlings was normal, and in the last two, the fifth, and third percent solutions, the growth of the seedlings was very slow.

During the period of germination of the seed a black fungus was noticed on the quartz sand under the paraffin. It did not appear in the weaker strengths but in the fifth and third percent solutions the germination of the seed was affected by it. On account of this condition the plants in these solutions did not get a good start until one month before harvesting time, when the growth was rapid. After the second month the condition of growth in the different solutions was reversed, i. e., the plants in the stronger solutions were rapid in their growth and those in the weaker solutions were very slow. At the end of the third month this change was quite marked. Except for the above-mentioned conditions the plants had a good normal growth.

The seed was planted on November 4, 1912, and harvested on March 24, 1913.

In all cases of normal growth of plants, more dry matter is found

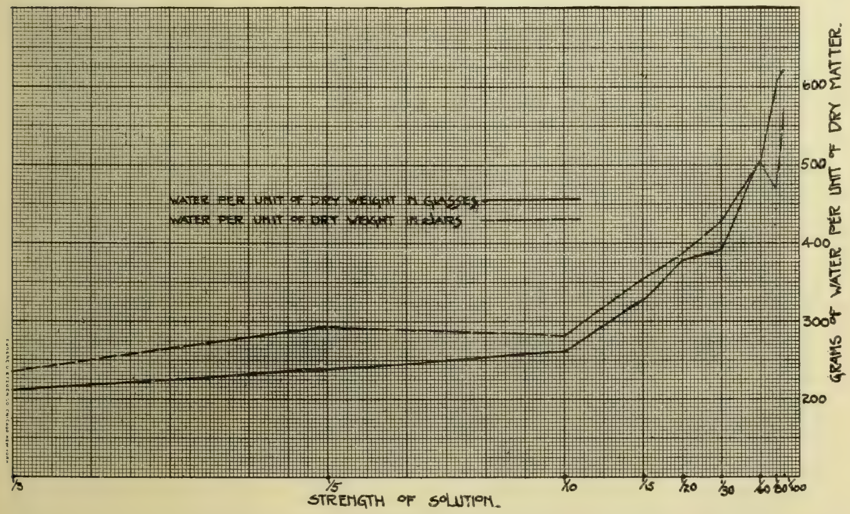

FIG. 1.—Graphs showing the increase in amount of water transpired per unit of dry matter with decrease in the strength of solution. Results from jars shown by solid line; from glasses by broken line. (N. B. In the cut the legend for these lines is reversed and incorrect.)

in the plants grown in stronger solutions than in the plants in the weaker ones. This fact was easily noticeable even when the plants were growing. Plants in the jars of concentrated solutions had good foliage, healthy appearance, and a taller growth than those in weaker solutions. After the young stage is passed plant growth serves as a good indicator of the strength of the soil solution. The average results from the two series of jars are shown graphically in Fig. 1, by the solid line.

The production of the largest quantity of dry matter in the strength of one tenth of one percent explains the statement elsewhere made that this concentration is the best for growing plants (wheat and oats) under the conditions existing here.

The other fact which Table 4 shows very clearly is that the amount of water required to produce a gram of dry matter is decreased when the strength of the solution is increased. A closer examination will show that there is very little difference between the results from the solutions of the first two strengths but there is a difference of about one hundred grams between the second and third. The second jar of the thirtieth percent solution shows lower results than the twentieth and fifteenth percent strengths but there seems to be an experimental error here. The averages of grams of water required per gram of dry matter, based on the jars of the same concentration, show a decrease without exception.

From the above results it is reasonable to assume that a soil richer in plant food will produce a greater yield than one less rich, even with a less amount of water.

Results obtained in experiments conducted last year at the Washington Experiment Station confirm the above-mentioned statement regarding the effect of the culture solution, as will be seen from Table 5.

The experiments conducted in the drinking glasses also show similar results, though not as accurately as the above. The growth of the

TABLE 5.—*Showing the Influence of the Strength of Solution on the Water Requirements of Oats and Wheat.*

Strength of Solution Used in Fractions of One Per Cent.	Grams of Water per Gram of Dry Matter Used by Oats.	Grams of Water per Gram of Dry Matter Used by Wheat.
1/250	758	1182
1/100	532	834
1/50	414	772
1/25	422	593
1/10	397	489
1/5	391	468

seedlings in these glasses was not as good as that in the larger jars. The glasses were planted with Washington Bluestem wheat on February 1, 1913, and harvested on April 15, 1913. These glasses were kept in a gardener's flat in order to shut out the light from passing through the roots. Though there was only one plant in a glass, the roots were crowded in it. The growth in the glasses was similar to that in the large jars. The plants in the weaker solution made a good growth to start with but in the second month the plants in the stronger solutions began to grow faster than the plants in the weaker solutions.

TABLE 6.—*Showing the Influence of Different Strengths of Nutrient Solution on the Water Requirements of Wheat Plants Two Months Old, Grown in Drinking Glasses, in Duplicate Series.*

Strength of Solution in Fractions of One Percent.	No. of Glass.	Total Amount of Dry Matter, Including Roots.	Total Water Transpired.	Water Used per Gram of Dry Matter.	Average of 2 Glasses.
		grams.	*grams.*		
1/100	1	.1158	46.65	402	....
1/100	2	.0678	49.85	734	568
1/80	1	.1210	51.20	448	....
1/80	2	.1238	60.90	492	470
1/60	1	.1250	66.50	532	....
1/60	2	.1328	63.60	479	505
1/30	1	.2176	110.80	510	....
1/30	2	.2816	97.50	346	428
1/20	1	.3582	157.60	440	....
1/20	2	.4162	138.90	334	387
1/15	1	.3064	110.50	361	....
1/15	2	.2094	72.30	345	353
1/10	1	.7268	224.40	308	....
1/10	2	.6452	166.00	257	282
1/5	1	.5122	168.00	327	....
1/5	2	.5788	151.00	261	294
1/3	1	.9850	216.20	219	....
1/3	2	.8546	214.80	251	235

The results from the duplicate series of experiments shown in Table 6 are not in accord, probably because of the following facts. First, the receptacles used to hold the sand were very small and consequently there was a smaller mass of soil than in the case of jar experiments. Second, the plants were young when they were harvested. Third, the addition of transpired water being always in parts of grams, as one tenth, three tenths, nine tenths, etc., involved extra precaution and labor. There was some loss of water from adhesion to the funnel or the spilling of a few drops. Fourth, the conditions under which such seedlings were grown were far from natural. Usually young plants have given less uniform results than plants which are fully grown. Harris[15] also noticed the same difficulty.

Though the results from the plants in the same strength of solution are varied, their averages indicate that plants in the stronger solutions require a less amount of water to produce a unit of dry matter than those grown in the weaker solutions. The averages for the plants in the sixtieth and fifth percent solutions are a little higher than those from the next weaker strengths but this seems to be due to an experimental error rather than to the concentrations of the solution. These results are shown graphically by the broken line in Fig. 1.

Harter,[16] Kiesselbach,[17] Bouyoucos,[18] and many other investigators also show that stronger solutions reduce the water requirements of plants.

Some investigators in working out the above problem have used only stalks and rejected the roots on account of the difficulty of removing the fine sand adhering to the roots and root hairs.[19] It is practically impossible to separate the quartz sand from the roots by the process of washing but this difficulty was overcome by burning the roots and dissolving the ashes in hot water and separating the sand from the ashes by decantation, similar to the method of separation of silts from sands in the mechanical analysis of soils.[20] This method gave accurate results in total dry weights of roots in culture solution experiments.

Table 7 shows the difference in results between the method in which only stalks are used and the one in which both the stalks and roots are used. All cases where only stalks have been used have given higher results in water requirements. This difference diminishes as the strength of solution increases. The variation in results from the hundredth to the thirtieth percent solution, inclusive, is from 467 grams to 307 grams. There is a sudden drop in the requirements in the case of the twentieth and fiftieth percent strengths. Between the

[15] Harris, F. S., Long versus Short Periods of Transpiration in Plants used as Indicators of Soil Fertility, Proc. Am. Soc. Agron., 2: 93.

[16] Harter, L. L., The Influence of a Mixture of Soluble Salts, Principally Sodium Chlorid, upon the Leaf Structure and Transpiration of Wheat, Oats and Barley, U. S. Dept. Agric. Bur. Plant Industry, Bul. 134: 14.

[17] Kiesselbach, T. A., Transpiration Experiments with the Corn Plant, Neb. Expt. Sta. Ann. Rept. 23: 138.

[18] Bouyoucos, G. J., Transpiration of Wheat Seedlings, etc., Proc. Am. Soc. Agron., 3: 130–191.

[19] Bouyoucos, l. c., p. 139.

[20] U. S. Dept. Agric., Bu. Soils, Bul. 24, p. 13.

TABLE 7.—*Showing the Difference in the Water Requirements Based on the Dry Matter of the Stalk Only, and on that of the Plant, Including Roots.*

Strength of Solution in Fractions of One Percent.	No. of Jar.	Stalks Only.		Stalks and Roots.		Difference of the Two.	Average Difference of Two Tests.
		Grams Water Used to Produce a Gr. of Dry Matter.		Grams Water Used to Produce a Gr. of Dry Matter.			
			Average of Two Pots.		Average.		
1/100	1	1,035	....	608	....	427	....
1/100	2	1,002	1,018	634	621	368	392
1/80	1	1,073	....	603	....	470	....
1/80	2	1,073	1,073	608	605	465	467
1/60	1	896	....	509	....	387	....
1/60	2	814	855	501	505	313	350
1/30	1	703	....	486	....	217	....
1/30	2	695	699	298	392	397	307
1/20	1	445	....	392	....	53	....
1/20	2	553	499	367	379	186	119
1/15	1	461	....	354	....	107	....
1/15	2	424	442	300	327	124	115
1/10	1	336	....	275	....	61	....
1/10	2	297	....	250	....	47	....
1/10	3	316	316	259	261	57	55
1/5	1	279	....	232	....	47	....
1/5	2	297	288	244	238	53	50
1/3	1	246	246	210	210	36	36

tenth and the third percent solution this fall is rather gradual. In general, the results show that, in the case of stronger solutions, the use of stalks only for the determination of water requirements does not show a very wide difference from the results of stalks and roots together, but in case of weaker solutions this difference is very great.

TABLE 8.—*Showing the Total Green and Dry Weights Produced in Each Strength of Solution.*

Strength of One Percent Solution in Fractions of	Total No. Jars Used.	Total Green Weight Without Roots.	Total Dry Weight Without Roots.
		grams.	*grams.*
1/100	2	8.873	2.8490
1/80	2	10.933	3.2748
1/60	2	13.910	4.2006
1/30	2	39.461	10.5546
1/20	2	95.846	23.0014
1/15	2	108.021	26.5632
1/10	3	424.635	99.6645
1/5	2	142.231	25.7963
1/3	1	71.027	13.9425

Table 8 shows that, in general, as the strength of the solution increases, the dry matter in the plant also increases. This fact is not new. It is the common experience of every farmer and experimenter that when the soil is rich it gives larger crops. In the one fifth and one third of one percent solutions, however, there is a very marked reduction in green and dry weights due to the abnormal growth of the plants, which did not get a good start, and some of which did not survive.

TABLE 9.—*Showing the Production of Dry Matter in Different Strengths of Solutions.*

Strength of Solution in Fractions of One Percent.	No. of Jar.	Green Weight Produced in Stalks.	Dry Weight Produced.	Percent Dry Matter.	Average of All Jars of the Same Strength.
1/100		*grams.*	*grams.*		
1/100	1	5.319	1.6170	30.40	....
1/80	2	3.574	1.1320	31.57	31.03
1/80	1	5.019	1.4910	29.74	....
1/60	2	5.914	1.7838	30.15	29.94
1/60	1	5.620	1.7010	30.28	....
1/30	2	8.290	2.4996	30.23	30.25
1/30	1	27.965	7.3296	26.22	....
1/20	2	11.496	3.2250	28.07	27.13
1/20	1	51.501	12.8430	24.93	....
1/15	2	44.345	10.1584	22.93	23.93
1/15	1	64.330	16.6432	25.87	....
1/10	2	43.691	9.9200	22.70	24.28
1/10	1	147.696	34.5237	23.37	....
1/10	2	137.341	32.2932	23.50	....
1/5	3	139.598	32.8476	23.51	23.46
1/5	1	90.255	16.5698	18.35	....
1/3	2	51.976	9.2265	17.76	18.05
	1	71.027	13.9425	19.60	19.60

TABLE 10.—*Showing the Weights in Grams of Stalks and Roots in Different Solutions.*

Strength of Solution in Fractions of One Percent.	No. of Jar.	Weight of Stalks.	Weight of Roots.	Total Dry Weight.	Average of All Jars of the Same Strength.
		grams.	*grams.*	*grams.*	*grams.*
1/100	1	1.6170	1.1382	2.7552	....
1/100	2	1.1320	.6578	1.7898	2.2725
1/80	1	1.4910	1.1660	2.6570	....
1/80	2	1.7838	1.3718	3.1556	2.9063
1/60	1	1.7010	1.3002	3.0012	....
1/60	2	2.4996	1.5710	4.0706	3.5359
1/30	1	7.3296	3.2830	10.6126	....
1/30	2	3.2250	4.2954	7.5204	9.0665
1/20	1	12.8430	1.7210	14.5640	....
1/20	2	10.1584	5.1476	15.3060	14.9350
1/15	1	16.6432	5.0014	21.6446	....
1/15	2	9.9200	4.0932	14.0132	17.8289
1/10	1	34.5237	7.6572	42.1809	....
1/10	2	32.2932	6.0028	38.2960	....
1/10	3	32.8476	7.2258	40.0733	40.1834
1/5	1	16.5698	3.4028	19.9726	....
1/5	2	9.2265	1.9928	11.2193	15.5959
1/3	1	13.9425	2.4052	16.3477	16.3477

On account of the luxuriant growth of the plants in most of the stronger solutions there is a greater total amount of dry matter produced but the percentage of dry matter in them is lower than in those grown in weaker solutions. Plants grown in one tenth of one percent solution had the largest growth but the percentage of dry matter was about the same as in one twentieth and one fifteenth of one percent solutions. From Table 9 it could be said in general that the percentage of dry matter decreases with the increase of strength of solution.

Table 10 shows that the total amount of dry matter is increased with the increase of strength of the solution. In case of the one fifth and one third of one percent strengths, the plants did not have a good stand for about the first two months; therefore the growth in those strengths is not comparable.

TABLE 11.—*Showing the Relation of Roots to Stalks by Weight of Dry Matter.*

Strength of Solution in Fractions of One Percent.	No. of Jar.	Percent Roots in Total Dry Weight.	Average of All Jars of Same Strength.	Percent Stalks in Total Dry Weight.	Average of All Jars of Same Strength.
1/100	1	41.35		58.65	
1/100	2	36.75	39.05	63.25	60.95
1/80	1	43.90		56.10	
1/80	2	43.50	43.70	56.50	56.30
1/60	1	43.35		56.65	
1/60	2	38.60	40.97	61.40	59.03
1/30	1	30.95		69.05	
1/30	2	57.10	44.02	42.90	55.98
1/20	1	11.82		88.18	
1/20	2	33.65	22.73	66.35	77.27
1/15	1	23.10		76.90	
1/15	2	29.20	26.15	70.80	73.85
1/10	1	18.17		81.83	
1/10	2	15.68		84.32	
1/10	3	18.06	17.30	81.94	82.70
1/5	1	17.02		82.98	
1/5	2	17.76	17.39	82.24	82.61
1/3	1	14.70	14.70	85.30	85.30

Table 11 shows that there was less growth of the roots, in proportion to the growth of the stalks, in the stronger solutions. Probably this is due to the reason that in the stronger solutions the plant food is readily available to the plants and consequently there is not much root development, and in the weaker ones, there being more demand for food, the roots penetrate deeper.

Table 12 shows more ash in the plants grown in the stronger solutions but this is due to good plant growth in those solutions. The percentages of ash in the plants grown in the different strengths of

TABLE 12.—*Showing the Ash Content and Percentage of Ash in the Plants Grown in Different Strengths of Solution.*

Strength of Solution in Fractions of One Percent.	No. of Jar.	Total Ash Produced in the Whole Plant.	Average of All Jars of Same Strength.	Percentage of Ash in the Whole Plant.	Average of All Jars of Same Strength.
		grams.	*grams.*		
1/100	1	.2466	....	8.95	....
1/100	2	.2430	.2448	13.58	11.26
1/80	1	.2397	....	9.02	....
1/80	2	.2299	.2348	7.29	8.15
1/60	1	.2166	....	7.21	....
1/60	2	.2620	.2393	6.44	6.82
1/30	1	.9074	....	8.55	....
1/30	2	.5874	.7474	7.81	8.18
1/20	1	1.0120	....	6.95	....
1/20	2	1.3173	1.1646	8.60	7.77
1/15	1	1.9214	....	8.87	....
1/15	2	1.3506	1.6360	9.63	9.25
1/10	1	3.5903	....	8.52	....
1/10	2	3.4168	....	8.93	....
1/10	3	3.4328	3.4799	8.57	8.67
1/5	1	2.5976	....	13.00	....
1/5	2	1.5456	2.0716	13.78	13.39
1/3	1	2.2808	2.2808	13.95	13.95

solution do not agree with each other, nor do they vary in any regular manner.

TABLE 13.—*Showing the Amount of Water, in Grams, used by the Plants to Produce a Gram of Ash.*

Strength of Solution in Fractions of One Percent.	No. of Jar.	Total Water Used.	Water per Gram of Ash.	Average Water per Gram of Ash.	Percent of Ash.
		grams.	*grams.*	*grams.*	
1/100	1	1,675	6,790	....	8.95
1/100	2	1,135	4,675	5,732	13.58
1/80	1	1,600	6,680	....	9.02
1/80	2	1,915	8,330	7,505	7.29
1/60	1	1,525	7,040	....	7.21
1/60	2	2,035	7,770	7,405	6.44
1/30	1	5,160	5,682	....	8.55
1/30	2	2,240	3,813	4,747	7.81
1/20	1	5,710	5,640	....	6.95
1/20	2	5,620	4,265	4,952	8.60
1/15	1	7,660	3,987	....	8.87
1/15	2	4,210	3,118	3,552	9.63
1/10	1	11,600	3,235	....	8.52
1/10	2	9,580	2,808	....	8.93
1/10	3	10,380	3,027	3,023	8.57
1/5	1	4,635	1,785	....	13.00
1/5	2	2,735	1,768	1,776	13.78
1/3	1	3,435	1,506	1,506	13.95

Table 13 is rather interesting because it shows that the water used per gram of ash is less in the stronger solutions; the one hundredth and one twentieth of one percent solutions are exceptions. From this it seems that plants grown in the stronger solutions containing more plant food do not take as much water in the process of building their tissues as they do in the case of weak solutions.

TABLE 14.—*Showing Comparison of the Water used per Unit of Dry Matter in Stalks and in Whole Plant, and Water used per Unit of Ash.*

Strength of Solution in Fractions of One Percent.	Water per Unit of Dry Weight, Stalks Only.	Water per Unit of Dry Weight, Whole Plant.	Water per Unit of Ash.
1/100	1,018E	621	5,732E
1/80	1,073	605	7,505
1/60	855	505	7,405
1/30	699F	392F	4,747F
1/20	499F	379	4,952E
1/15	442	327	3,552
1/10	316	261	3,023
1/5	288	238	1,776
1/3	246	210	1,506

Table 14 explains the rôle of different strengths of solution in water requirements of plants. The water per unit of dry weight and also per unit of ash is decreased with the increase in concentration of solution. The figures marked with "E" are exceptions and those marked with "F" have a sudden fall or decrease in water per unit.

AGE OF THE PLANT AS A FACTOR INFLUENCING THE WATER REQUIREMENTS OF CROPS.

These experiments were carried on in the pure quartz sand, using a tenth of one percent culture solution to water the plants, and in the Palouse soil, using faucet water for watering. Jars containing quartz sand were sealed with paraffin and the jars containing the Palouse soil had about one inch of sand mulch. The methods used in the preparation of jars, etc., have already been described. Other conditions were the same as in the preceding experiments.

Table 15 contains the results of experiments conducted in pure quartz sand in the greenhouse.

This table shows that the water requirement of a wheat plant in the first period of fifty days is greater than in the second period of ninety days. Also that in the third period the water requirements are less than in either the first period or the second period. The individual results for the different periods show the same thing though the second and third periods do not check as nicely as the first.

TABLE 15.—*Showing the Green and Dry Weights Produced and the Amount of Water used by a Wheat Plant at Different Periods of its Growth, (Wheat Grown in Pure Quartz Sand).*

Period, Days After Germination.	No. of Pot.	Green Weight.	Dry Weight.	Percent Dry Matter.	Water Used per Gram of Dry Matter.	Average.
		grams.	*grams.*		*grams.*	
1st period, 50 days.........	1	8.410	1.0000	11.89	420	......
	2	9.205	1.0968	11.91	423	......
	3	7.768	.9177	11.81	424	422
2d period, 90 days.........	1	44.328	6.8558	16.39	355	......
	2	59.408	10.1165	18.18	357	......
	3	35.990	5.2914	15.84	376	362
3d period,[21] 137 days.......	1	147.696	34.5237	23.37	275	......
	2	137.341	32.3732	23.50	250	......
	3	139.598	32.8476	23.51	259	261

[21] Green and dry weights given in this table are of stalks only. On account of the sand, green weights of roots were not determined. The dry weight of roots was added to the dry weight of the stalks and this total dry matter was used in the calculation of water requirements. Dry weight of roots in pot No. 1 = 7.6572, No. 2 = 6.0028, and No. 3 = 7.2258.

This table also shows that the percentage of dry matter increases with the age of the plants. This seems to be the main reason why the water requirement of plants in the young stages is higher than in the older stages. From the above results it is reasonable to assume

TABLE 16.—*Showing the Green and Dry Weights Produced and the Amount of Water used by a Wheat Plant at Different Periods of its Growth, when Grown in Palouse Soil.*

Period, Days After Germination.	No. of Pot.	Green Weight.	Dry Weight.	Percent Dry Matter.	Water Used per Gram Dry Matter.	Average.
		grams.	*grams.*		*grams.*	*grams.*
1st period, 50 days.........	1	5.08	.7050	13.87	581	......
	2	5.10	.7115	13.75	576	......
	3	4.91	.6620	13.48	619	592
2d period, 90 days.........	1	23.043	4.0932	19.56	447	......
	2	22.408	4.4833	21.81	437	......
	3	22.896	4.0291	17.37	424	436
3d period,[22] 137 days.......	1	30.770	10.1610	33.06	293	......
	2	24.320	7.2086	33.73	364	......
	3	33.938	11.2650	33.19	281	312

[22] Green and dry weights given in this table are of stalks only. On account of sand, the green weights of roots were not determined. The dry weight of the roots was added to the dry weight of the stalks and this total dry weight was used in determination of water requirements.

Weight of the roots in Pot No. 1 = 3.2244, No. 2 = 2.2666, and in No. 3 = 3.4328 grams.

that experiments conducted in one period of plant growth will not be representative for all the periods, and in order to determine the water requirements of the crops for practical value, it is necessary to use full-grown plants.

Table 16 also shows that the plants take more water in the first period of their growth than in the second period; and more in the second period than in the third. There is an increase in percentage of dry matter as the plants approach maturity.

TABLE 17.—*Showing the Amount of Water Required to Produce a Unit of Dry Matter in Oats at Different Periods of Plant Growth (Plants Grown in Palouse Soil).*

Periods.	Water Required to Produce a Unit of Dry Matter.
	grams
1st Period, 30 days after planting	519
2d Period, 60 days after planting	482
3d Period, 90 days after planting	369

Experiments conducted under out-door conditions at the Washington Experiment Station[23] show similar results with oats and these are presented in Table 17.

TABLE 18.—*Showing the Influence of Age of Plant on Water Requirements of Plants Grown in Different Strengths of Culture Solution.*

Strength of Solution in Fractions of One Per Cent.	Water Used per Unit of Dry Matter in Plants Two Months Old.	Water Used per Uni of Dry Matter in Plants Four and a Half Months Old.
	grams	*grams*
1/30	428	392
1/20	387	378
1/15	353	327
1/10	282	261
1/5	294	238
1/3	235	210

Pure quartz sand was used as a medium in which to grow the plants and pots were sealed. The only difference in the procedure for the experiment recorded in Table 18 is that, for younger plants, smaller pots were used than were used for the full-grown plants. Otherwise the treatment was alike. Table 18 shows that in every case plants two months old have used more water per unit of dry weight than the mature plants.

[23] Washington Experiment Station, unpublished experiments, 1912, Duty of Water Record, p. 114.

AMOUNT OF MOISTURE IN THE SOIL AS A FACTOR INFLUENCING WATER REQUIREMENTS OF PLANTS.

These experiments were carried out in pure quartz sand and in Palouse soil. In the first case, pots were sealed and watered with the culture solution and in the second a heavy mulch was kept and the plants were watered with the faucet water.

The experiments recorded in Table 19 were carried on in sealed pots containing pure quartz sand and which were watered with one tenth of one percent culture solution. Eight and sixteen percent, respectively, of soil moisture were maintained in the two series. All other conditions were the same.

TABLE 19.—*Showing Soil Moisture as a Factor Influencing Water Requirements of Plants in Quartz Sand.*

Percentage of Soil Moisture.	Number of Jar.	Water Required to Produce a Gram of Dry Matter.	Average of 3 Pots.
		grams.	
8 percent	1	243	
8 percent	2	226	
8 percent	3	257	242
16 percent	1	245	
16 percent	2	289	
16 percent	3	303	279

This table shows that the water required by a crop increases with the increase of the soil moisture.

The experiments using Palouse soil were carried on in the two-gallon jars and one inch of sand mulch was kept on the surface. The results obtained are given in Table 20.

TABLE 20.—*Showing the Soil Moisture as a Factor Influencing Water Requirements of Wheat Grown in Palouse Soil.*

Percentage of Soil Moisture.	Number of Jar.	Water Required to Produce a Gram of Dry Matter.	Average of 3 Jars.
		grams.	
10 percent	1	325	
10 percent	2	242	
10 percent	3	257	274
20 percent	1	271	
20 percent	2	299	
20 percent	3	291	287

This table also shows that plants grown in the soil having greater saturation take more water to produce a unit of dry matter than the plants grown in the soil of less saturation.

TABLE 21.—*Showing the Relation of Soil Moisture to Plant Growth and Percentage of Dry Matter (Wheat Grown in Palouse Soil).*

Percentage of Soil Moisture.	No. of Jar.	Green Weight.	Dry Weight.	Per cent Dry Matter.	Average of Three Jars.
		grams.	*grams.*		
10 percent	1	14.580	4.9298	38.80	
	2	11.940	4.9832	41.78	
	3	13.450	5.2127	38.74	39.77
20 percent	1	45.229	14.1625	31.30	
	2	44.370	14.6390	33.04	
	3	41.689	13.8390	33.20	32.51

Table 21 shows that when there is more moisture in the soil there is a larger growth of the plant. But the growth of the plants does not give an idea of the percentage of dry matter. Table 21 shows that plants grown in ten percent of soil moisture produced less growth but contained higher percentages of dry matter than the plants grown in twenty percent of soil moisture. There is a decrease in the percentage of dry matter with an increase in percentage of soil moisture.

The Washington Experiment Station[24] also obtained results that show the increase in soil moisture increased the amount of water required per unit of dry matter. These data are given in Table 22.

TABLE 22.—*Showing that the Quantity of Water Required to Produce a Gram of Dry Matter is Increased with the Increase in Soil Moisture.*

Percentage of Capillary Saturation.	Grams of Water Required to Produce a Gram of Dry Matter in Wheat.
50	298
35	275

Experiments[25] in 1911 show that oats grown in Palouse soil containing twenty, fifteen, and ten percent of soil moisture have used 453, 421, and 171 grams of water to produce a gram of dry matter.

Montgomery[26] and Harris[27] also obtained similar results.

THE INFLUENCE OF TEMPERATURE AND HUMIDITY ON WATER REQUIREMENTS.

These experiments were carried out in pure quartz sand and the jars were sealed. There were only three jars in all. Earth was placed under different conditions of humidity and temperature in the greenhouse. Plants were watered with one third of one percent solution. The results are shown in Table 23.

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[24] Thom, C C., Unpublished experiments, Washington Experiment Station.

[25] Washington Experiment Station, Unpublished experiments, Field No. 3 Record, p. 71.

[26] Montgomery, E. G., Methods of Determining the Water Requirements of Crops, Proc. Am. Soc. Agron., 3: 276, (1911) 1912.

[27] Harris, F. S., Long versus Short Periods of Transpiration in Plants used as Indicators of Soil Fertility, Proc. Am. Soc. Agron., 2: 100, (1910) 1911.

TABLE 23.—*Showing the Influence of Temperature and Humidity on Water Requirements of Wheat Grown in Quartz Sand.*

Room No.	Nature of the Room Where Experiment Was Carried On.	Amount of Water Used to Produce a Unit of Dry Mat.
1.	Room having low relative humidity	385
2.	Room having medium relative humidity	483
3.	Room having high relative humidity	323

The best plant growth occurred in room No. 3; a medium growth in room No. 2, and the lowest in the room No. 1. There was more total dry matter in the plants grown in No. 3 than in No. 2, and in those of No. 1 less than in No. 2 or No. 3. A larger percentage of dry matter was produced in the plants grown in room No. 3. Plants in rooms No. 1 and 2 had the same percentage of dry matter.

Conclusions cannot be drawn from this experiment because there were no duplicates to check the results.

SUMMARY.

The problem of the water requirements of crops is very important. The factors which are commonly considered to influence water requirements of crops are many, but the most of them are speculative and but few empirical. The interest in this subject is new and consequently not much investigation has been made.

The above-described experiments were carried on with the view of ascertaining more in detail some of the factors which influence water requirements of wheat.

Every possible precaution was taken to avoid experimental errors. Standard and efficient methods were used in the investigations. Experiments were carried on in pure quartz sand, in sealed jars, and plants were watered with definite strengths of nutrient solutions. In order to ascertain the factors influencing water requirements under natural conditions, some experiments were carried on in the Palouse soil.

The experiments show the following factors to influence the water requirements, namely, (1) kind of crop, (2) strength of soil solution. (3) age of plants, (4) amount of moisture in the soil.

1. *Kind of Crop.*—Different kinds of crops take different amounts of water to produce a unit of dry matter.

2. *Strength of Soil Solution.*—The strength of soil solution has

influence on water requirements of plants. The amount of water to produce a unit of dry matter is decreased when the strength of solution is increased. Popularly speaking, a fertile soil will produce a greater yield with a less amount of water than will infertile soils, under similar conditions.

3. *Age of Plants.*—Younger plants take more water than the older plants. The experiments show that the plants in the first period of their growth take more water than in the second period; and in the second period they take more than in the third.

4. *Amount of Moisture in Soil.*—The plants grown in the soil having more saturation take more water to produce a unit of dry matter than the plants grown in the soil of less saturation.

STERILE FLORETS IN WHEAT AND OTHER CEREALS.

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Floret sterility frequently occurs in the cereal crops in the Great Plains. The damage resulting therefrom is considerable and apparent to the most casual observer. It may be induced by drought (Pl. I, Fig. 1), hot winds, insects or parasitic fungi or by the combined action of two or more of these factors. Whatever the cause, the usual forms of sterility are too well known to require discussion herein. The purpose of this paper is to consider a condition of sterility which, though closely associated with drought and hot winds, is due, in the opinion of the writer, to neither as such. It may be designated as "floret sterility," since the individual florets are the structures affected by the disease.

Floret sterility is characterized simply by failure to produce grain. The appearance of the head and glumes is perfectly normal except that the glumes are less distended than in well-filled heads, in which sterile florets are easily detected because of the contrast. In durum and other wheats with stiff glumes and in seasons when the upper florets of the spikelets do not fill, sterile florets or even sterile heads may appear perfectly normal (Pl. I, Fig. 2). For this reason there may be considerable loss from sterility without its presence being suspected. Unlike the usual forms of blight, sterile florets are not confined to a particular part of the head (Pl. II, Fig. 1). They may occur in groups at the base, the tip, or the middle of the head, or they may be scattered, some at the base, others at the tip, and still others in the middle. One floret of a spikelet may be sterile though the other contains kernels.

Material damage from floret sterility was first observed at the Bellefourche Experimental Farm at Newell, S. D., in 1910. This was a very dry, hot season. It was, therefore, a matter of some surprise that the durum wheats produced smaller yields than the spring common varieties, although the appearance of the former in the field and the quantity of straw produced indicated the opposite result. On investigation it was found that this condition had occurred at other field stations in the Great Plains in both 1910 and 1911, two of the

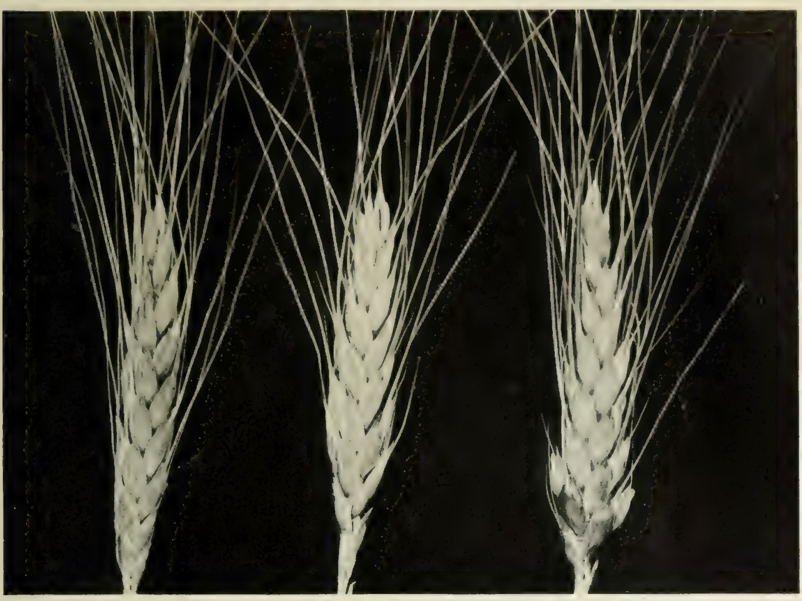

FIG. 1.—Heads of Kubanka durum wheat completely sterile from protracted drought.

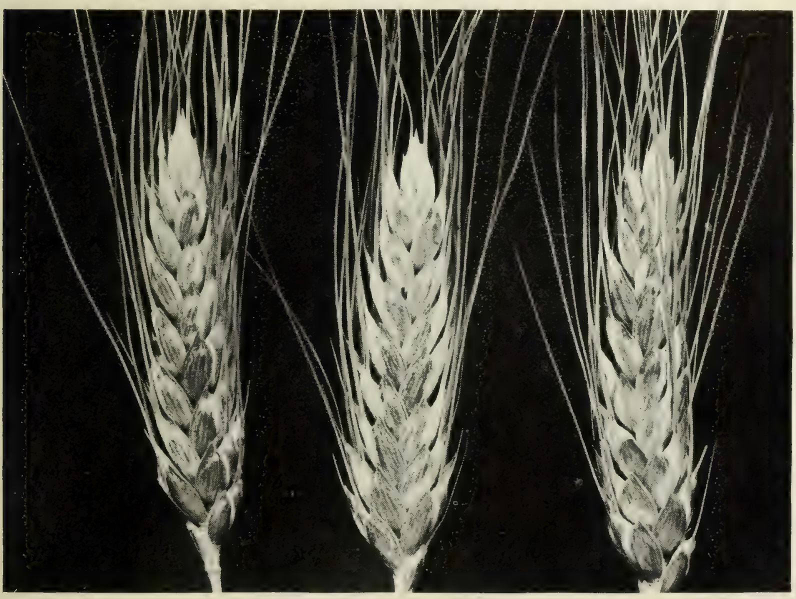

FIG. 2.—Heads of Kubanka durum wheat normal in appearance but 63 per cent. sterile.

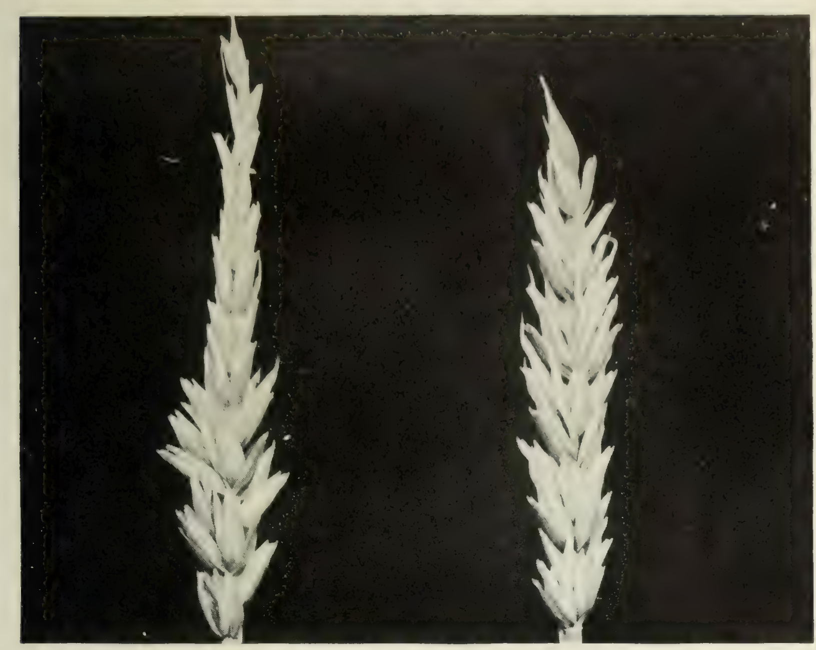

FIG. 1.—Heads of Ghirka spring wheat showing sterile florets.

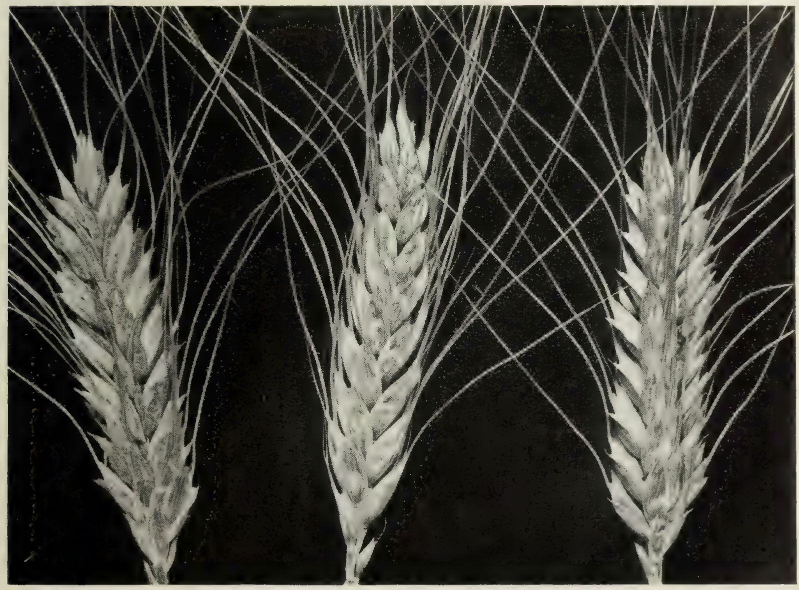

FIG. 2.—Heads of Kubanka durum wheat showing chaffy spikelets.

driest and hottest years known in the agricultural history of this area. As the durums, since their introduction, had produced better yields than the spring common wheats, their falling off in yield in the two seasons when of all others they should have demonstrated their value, constituted a problem considered worthy of further study.

Some data obtained in 1910 indicated that sterility from some cause was the chief factor concerned in the relatively low yield of the durums. The season of 1911 produced a complete crop failure at the Bellefourche farm, so that no observations were possible. Conditions in 1912 were more favorable. In that season, a rather large number of durum wheat heads were found with open glumes, giving the head a chaffy appearance (Pl. II, Fig. 2). This was soon after flowering, and coincident with a period of exceptionally warm weather. Since the opening of the glumes, except for a very short time, is an abnormal condition in wheat, 32 of the heads were tagged and when ripe were examined for sterility. The percentage of fertile spikelets was found to vary from 0 to 100 in the individual heads. The average for all the heads showed that 38 percent were fertile and 62 percent sterile, while 10 of the 32 heads were 90 percent sterile.

In view of these results it was thought that a definite relation existed between the presence of open glumes and sterility and also between the hot weather during the flowering period and sterility. Since the heads appeared to be perfectly normal except for the open glumes, it seemed that failure to fertilize might, perhaps, have been the immediate cause. Accordingly, at the beginning of the crop season of 1913, experiments were planned to determine (1) the relation between high temperatures during the flowering period and sterility, (2) between the presence of open glumes and lack of fertilization, and (3) between the presence of open glumes and cross fertilization.

Effect of High Temperature and of Low Humidity.

To determine if any relation existed between high temperature and sterility, a box 12 × 16 × 24 inches, with glass sides and top, was constructed so that it could be inverted over the heads of growing wheat. A gasoline burner was arranged to supply heated air below the heads of the plant and small holes were made in the sides of the box at the top for the escape of air. This apparatus was first used on winter wheat during the flowering period. Treatment began at 6.00 a.m. and was continued 1¾ hours, the temperature ranging from 30° to 40° C. Forty-eight heads containing 1,089 florets were treated, of which 19.4 percent proved to be sterile. The percentage of sterility of the same number of untreated heads from the same plat and like stage of growth was 7.4 percent, or 12 percent less than in the treated heads.

In the second test, also with winter wheat, treatment was begun at 4:20 a.m. and continued all day, the temperature ranging from 35° to 40° C. Fifty-seven heads containing 1,180 florets were treated, and the same number of untreated heads from the same plat and like stage of growth, containing 1,338 florets, were selected for comparison. The sterility in the treated heads was 28.4 percent and in the untreated 9.6 percent, a difference of 16.8 percent.

A third test was made with durum wheat in which treatment was begun about 4:20 a.m. on four consecutive mornings, the temperature being maintained at from 35° to 40° C. for about three hours each day. Forty-eight heads containing 1,247 florets were treated and 52 untreated heads from the same plat and like stage of growth were selected for comparison. The percentage of sterility in the treated heads were found to be 35.3 percent and in the untreated, 9.6 percent, a difference in this instance of 25.7 percent. In each of these three tests, the open glumes and chaffy appearance of the heads, which had been found to be associated with sterility the previous season, were again present.

In conducting these experiments, certain phenomena were observed which indicated that dryness of the air rather than the high temperature was the controlling factor. An experiment was therefore planned to determine this point. Some heads were inclosed in the glass box as before and the box was shaded to prevent undue rise in temperature from the heat of the sun. A quantity of calcium carbide was then placed in shallow receptacles about the inclosed heads, to dry the air. Though no means were at hand for insuring circulation of air about the heads, the treatment resulted in 34.3 percent of sterility as compared with 19.4 percent for those not treated. In each case, over 500 florets were examined.

In another trial, a single head was inclosed in a smaller box, as it was thought the air could be more thoroughly dried therein. This treatment resulted in 75 percent of sterile florets. Twenty heads from the same plat and stage of growth were selected for comparison, the aim being to select those heads with the largest apparent percentage of sterility. The average sterility of these heads was found to be 5.3 percent, and the highest proportion of sterility in a single head was 14.3 percent. The temperature during both of these tests was rather high. As it was not under control, it may have been a contributory factor.

In view of the high percentage of sterility observed in the durum wheat heads selected from the field the previous season, more decisive results than those recorded in the above experiments might have been expected. Admitting the relation between sterility and high temperature and dryness of the air the failure of the experiments to demonstrate it more forcibly may possibly be explained in any one of several ways. The flowering-period of wheat and other cereals extends over several days. Only a part of the flowers, therefore, bloomed during treatment and, as will be shown later, a part of those treated may have become fertilized with pollen from other flowers. The varieties treated were not the same, and this may have been a factor. And, finally, the apparatus was rather crude, especially in that provision was not made for insuring a circulation of air about the heads, such as would take place in the field.

Drought, hot winds, and disease have also been considered as possible causes of floret sterility and undoubtedly they do cause certain forms of the disease. At the Bellefourche farm, no indications that the disease may be due to parasitic organisms have been found, though this phase of the subject has received considerable attention. As to drought and hot winds, it is probably sufficient to state that sterile florets have been found in plants which certainly were subject to neither of these conditions.

While the data here presented may not be conclusive, they appear to indicate strongly a causative relation between certain atmospheric conditions (high temperature and low relative humidity) during the flowering period and floret sterility, with evidence that the low relative humidity rather than the high temperature is the principal factor involved.

Relation between Nonfertilization and Open Glumes.

A simple experiment was performed during the present season to determine the relation between failure to fertilize and the occurrence of open glumes. The anthers of about 200 florets of wheat were removed while yet green, and the heads bagged to prevent wind pollination. Two days later a part of the glumes were observed to be open and at the end of four days practically all the glumes were wide open, fully exposing the stigma. Excepting in a few flowers which were hand pollinated, these glumes remained open until the stigma began to die, which took place in eight to ten days.

From this experiment, it appears that floret sterility is due simply to the failure of the flowers to become fertilized because of a very dry atmosphere or possibly a high temperature. Though definite data are lacking, the appearance of the anthers indicates that they are the organs which are injured. In some cases at least they remain inside the glumes and probably do not distribute pollen, or else the pollen is not viable. As previously stated, the appearance and behavior of the plant does not indicate an abnormal condition in any other part.

Sterile florets seem to be rather common at the Bellefourche Experiment Farm and presumably elsewhere in the Great Plains. Ten percent of sterility in wheat is rather common, and as much as 50 to 75 percent has been observed. The open glumes and chaffy appearance of the head indicative of sterility have been observed in all of the cereals grown on the Bellefourche farm.

Loss from sterile florets appears to be of special importance in the case of winter rye. Admitting that sterility is caused by low relative humidity or high temperature during the flowering period, it would seem that, since rye is one of the earliest cereals and consequently blooms usually during cool weather, it would be the least subject to loss. However, if the observations of the writer are correct, rye, of all the cereals, is the most liable to sterility.

This condition was well illustrated at the Bellefourche farm in 1913. A period of moderately warm weather occurred when the winter wheat and rye were in flower, the rye being about a week in advance of the winter wheat. The average morning temperature during the flowering period of the wheat was nearly 15° F. higher than during the flowering period of the rye. The percentage of sterility in each was determined from about 50 heads picked at random. One determination in the wheat showed 7.4 percent sterility and another, 9.8 percent, while a single determination in the rye showed that 74.3 percent of the florets were sterile. The rye was also damaged by hail, being at a more critical stage of growth than the wheat. In making the determination for sterility, however, heads were selected which the hail had not damaged. The highest yield from 3 plats of rye was 6.5 bushels to the acre, with an average of 5.3 bushels. Three plats of winter wheat adjoining the rye produced an average yield of 38.7 bushels to the acre, the highest yield being 40.1 bushels. It is of course impossible to say how much of the reduced yield in rye was due to floret sterility and how much to the hail; the writer's judgment is that the rye would not have produced over 15 bushels had there been no hail. In general, rye does not produce satisfactory yields of grain on the Bellefourche farm and, though sterile florets have not been generally observed, there is little doubt that their presence has been a factor.

Again, if it is assumed that floret sterility is associated with dryness of the air and high temperature during the time that the flowers are actually in bloom, the greater damage to the rye may be explained by its flowering habits. As is well known, wheat and most other cereals bloom only in the morning. It is exceptional to find wheat in bloom after 7:00 a.m. under normal conditions, while rye blooms throughout the day. Apparently, blooming takes place as abundantly in the middle of the day as at any other time. Thus, while wheat blooms when the temperature is lowest and the humidity greatest, a part at least of the rye florets bloom during the hottest and driest part of the day. This habit and the resulting sterility may partly explain the tendency of rye to cross-pollinate. When rye blooms under normal conditions there is abundant opportunity for close pollination, but if the pollen is killed or prevented from germinating on the stigma, fecundation may be effected through cross-pollination.

RELATION BETWEEN OPEN GLUMES AND CROSS-FERTILIZATION.

The tendency of wheat and other normally close-fertilized cereals to cross-fertilize under semiarid conditions may also be explained in this way. As previously stated, when viable pollen does not reach the stigma of wheat, the glumes remain open, exposing the stigma to the air and presumably to wind-pollination. To determine to what extent this might take place, the anthers of 199 florets of wheat were removed before they were ripe, the heads remaining exposed to the air. One hundred and fifty-two of these, or 76.3 percent, produced grain. A single head similarly treated except that it was bagged produced no grain whatever. From this it appears that there is abundant opportunity for wind-pollination and cross-fertilization if, as appears to be the case, the open glumes are indicative of lack of fertilization.

There is considerable evidence to show that the tendency in wheat to cross-fertilize is greatest in semiarid regions where the dryness of the air, the high temperatures, and the absence of morning dew would appear to induce floret sterility. Thus Howard et al.[1] report 226 field crosses occurring in a single year in the arid climate of India, and state that the tendency to cross-fertilize interferes seriously with breeding operations. In a more humid section of the same country, these investigators state that little trouble from cross-fertilization is experienced. They also are to be credited with the statement that "In Northern Europe cross-pollination in wheat is a rare occurrence; in warmer climates it is more frequent. But where the crop can only be grown by means of artificial irrigation, cross-pollination is quite common." The presence of open glumes and the exposure of the stigma to the air was observed by these experimenters, but was thought to be due to the wilting of the plants during the hottest part of the day as a consequence of the low moisture content of the soil. Cook[2] observed open glumes with the stigma exposed on the wild and domesticated wheats of Palestine, and explains the phenomena in the former by assuming that it is naturally cross-fertilized.

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[1] Howard, A., Howard, Gabrielle C., and Khan, Abdur Rahman, The economic significance of natural cross-fertilization in India, Memoirs of the Department of Agriculture in India, botanical series, 3: 302–3, October, 1910.

In a general way it appears that the observations of Howard et al. regarding the tendency to cross-fertilize in hot, arid climates also holds good for the United States. Natural hybrids are seldom observed in the humid wheat-growing districts east of the Missouri River but in the Great Plains, particularly in the central portion, field crosses are more common. They also appear to be more plentiful during hot, dry seasons than in cool, moist ones.

Conclusion.

A knowledge of the cause of sterile florets would appear to be of value in a direct, practical way. There may be differences in the extent to which different varieties of the cereal crops resist damage; certainly, there is a great difference in their ability to escape damage. It would seem that early varieties would, on the average, be the least subject to sterility, and it is likely that the danger of loss from sterile florets would be an additional argument in favor of early seeding. This especially may be worthy of emphasis in irrigated districts where there is a tendency to ignore the advantages of early seeding when water is plentiful and certain.

[2] Cook, O. F., Wild wheat in Palestine, U. S. Department of Agriculture, Bureau of Plant Industry. Bull. 274: 13–19, 1913.

COMMUNITY GROWING OF CROP VARIETIES.

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In a recent number of this journal Mr. C. R. Ball comments favorably upon two papers by Cook and MacLachlan which present the needs and advantages of community action in the production of cotton. He then takes the rather advanced stand that similar if not equally good results are to be expected from community action in the production of pure strains of cereals and some other field crops. His attitude may be summarized in two of his sentences: " First, that the very idea of mixtures should be persistently discredited as being fundamentally wrong from the standpoint of good farming," and " Only in purity is there safety."

Is it not possible that in his enthusiasm over the case presented by Cook and MacLachlan Mr. Ball has gone too far in extending the community idea to the cereal crops, and in affording to others the occasion, if not the suggestion, to extend it even to the forage crops? How would it look to find some agricultural evangelist advocating that one community should grow only timothy, another clover, and another red top to insure purity in the hay crop, and because mixtures are fundamentally wrong from the standpoint of good farming?

Of course, it is unlikely that any well-informed person would go so far as to recommend purity in hay crops. Common experience has demonstrated too clearly the superior value of mixtures. But is it advisable to press the case even for the cereal crops?

To avoid unnecessary confusion it may be well to consider this matter first, from the standpoint of the farmer as an individual, and second, from the standpoint of the farmer as a member of the community.

From the standpoint of the farmer as an individual the direct question is: Should only one variety of the same crop be grown on the same farm or in the same field? For the sake of the farmer let us consider the evidence in the case. A cursory glance through the indexes of United States Experiment Station literature leaves the impression on the mind that this subject has been but little investigated. There are, of course, numerous experiments reported in which carefully selected varieties have been compared with the mixed parent stock from which selection was made. These experiments have yielded diverse results. In general the selected variety has outyielded the parent stock, but not always. But granting that this is the general rule, does this justify the generalization that mixtures are to be avoided? What about intentional mixtures of selected varieties in comparison with either or both of the selected varieties grown separately? There are but few such comparisons recorded in our agricultural literature. Two cases of this sort have come to my notice, one from Kansas and the other from Missouri.[1] In the first case all the mixtures but one outyielded the average of the selected stocks, and in the second case all of the mixtures outyielded the average of the selected stocks. In the Missouri Bulletin the result of experiments are summarized on the title page and printed in heavy italics: "A mixture of varieties has resulted in an increased yield over the average of the same varieties grown separately." These experiments may be open to serious technical objections as evidence favoring the practice of mixing varieties, but until the matter has been thoroughly canvassed it might be well to proceed with caution on the same track in the opposite direction.

As a matter of fact I have been told by Mr. F. D. Farrell that it has been a common practice of good farming in certain sections of the Great Basin to sow mixtures of two varieties of wheat. In this case the end sought was to avoid lodging and the practice was to mix with a high-yielding variety having soft straw a variety which had a short stiff straw.

This practice may be fundamentally wrong from the standpoint of good farming but if it gives the farmer more wheat and more money per acre without added cost may it not be worth while?

Another query suggests itself to me. Cerealists who are familiar with conditions in the Dakotas know that two varieties of oats, Sixty Day and Swedish Select, have very different habits of growth and that one of them ripens much earlier than the other. In that region where good growing seasons are interspersed with seasons of early summer drought or hot winds may come before harvest time, it is an open question as to which of these varieties will give the best returns during a long period of years. How would it be to let the farmer "hedge" a little by using both varieties, not in the same field perhaps but at least on the same farm?

[1] Georgeson, C. C., Experiments with Wheat, Kans. Expt. Sta. Bull. 20: 10, July, 1891.

Connor, C. M., Field Experiments with Wheat, Mo. Expt. Sta. Bull. 21: 14, April, 1893.

It is a well-recognized farming practice to mix seed of wheat and rye for planting, particularly in France where the crop is known as *meteil.* In America, both in the United States and in Canada, it is also a common practice to mix wheat and oats, and oats and barley. There is good evidence as well as a common belief that these mixtures result in better yields than could be secured from the same crops planted separately. The reason for this may be surmised even if it is not known definitely. But it is idle here to speculate on that phenomenon. If it is a fact that mixtures of different kinds of grain yield better than the same grains do separately is it not possible that a judicious mixture of two or more varieties of the same kind of grain might also yield better than the same varieties grown separately? At least the matter may be worth further investigation.

So much for the small grains on the individual farm. The small grains are mostly self-fertilized while corn like cotton is open-fertilized. Yet the purity of corn varieties may be overdone from an agronomic standpoint. It has been clearly demonstrated both by early experimenters and more recently by Collins and Hartley that first-generation hybrids in corn outyield the average of the parent varieties. This may not be an argument in favor of the use of mixed or mongrel varieties of corn but at least there is good reason for believing that the proper mixture of varieties in the seed plat is about the cheapest and surest way to add 10 percent to the yield of the individual farmer's corn crop, and furthermore this may be done without lessening in the least the market value of that crop.

Now consider the matter from the standpoint of the farmer as a member of the community. Are the advantages to be gained as set forth by Mr. Ball sufficient to warrant either the effort to secure community action in the matter or to offset injury that might result from the selection of the wrong variety for the community to adopt? When one reflects on the difficulties we encounter now in spreading the use of a new crop or in getting a new variety grown as extensively as we may believe its superiority merits the task of doing this where the whole community must be moved at once looks like a colossal one. As it is now, we can at least pour a little leaven into the mass. We can find a few progressive farmers in almost every community willing to give a new thing a fair trial. But if these progressives were to be held back by the veto power of their reactionary neighbors, the adoption of a new variety would involve a local revolution. This is the real problem which confronts community cotton growing. But in cotton the end appears to justify the means. The need of community action in cotton growing and of the use of one variety of cotton in each community is due to certain peculiarities in the handling and manufacture of cotton which do not exist or which are much less important in other field crops. Uniformity is one of the most important, if not the most important, factor in determining the commercial value of cotton. Manufacturers desire and are willing to pay a premium for uniformity. They want the cotton uniform not only in length and grade but they want it uniform through the bale, throughout the consignment and also uniform from season to season. The discrimination of the manufacturers in favor of uniformity in cotton or aganist the lack of it is only one feature of the case. This same discrimination is in effect contributed all along the trade channels between producer and manufacturer. There is much less of this sort of discrimination either in the handling or manufacture of the other field crop products.

Much the same forces and factors that operate in the handling of cotton to discriminate against lack of uniformity also operate to discourage the commercial production of new and improved cotton varieties in any community. The individual cotton farmer who produces a few bales of long staple cotton in a community where only short staple cotton has been produced finds the greatest difficulty in marketing his crop for what it is really worth. The local buyers are not familiar with the new type of cotton, the brokers in distant markets are skeptical, and the manufacturers are disinclined to experiment with small lots. Furthermore, the farmer with the improved cotton is subjected to the risk of its contamination both by cross pollination from neighboring fields and by mixture of seed at the gin. All these features are of critical importance in connection with the cotton crop. It has been claimed by Mr. Cook that community action will help to overcome these difficulties, and that further progress in the improvement of our cotton crop awaits this action. But Mr. Cook has remarked that community action in selecting a cotton variety may require some form of local option voting. Certainly to change a community from one type or variety of cotton to another may prove to be no less serious a task than to get it organized to adopt some one type in the first place.

While it seems clear that in cotton production further improvement is impossible without community action, it is not apparent that the same is true for the cereals or other farm crops. Certainly not in the same degree. Durum wheat has been introduced and has spread like a great wave over the northern Great Plains, without community action and without injuring the quality of the bread wheats formerly grown. Anything analogous to this could not happen in cotton.

It is not my purpose to belittle the need of community action which is another name for rural organization. There is acute need of it in the cotton producing industry and there is ample need of it in improving our breeds of livestock. It is needed no less in many other phases of rural life. There is an abundance of texts from which to preach this sermon, but I am slow to believe that the one Mr. Ball selected is among the best adapted to our present needs.

The following quotation from the paper[2] under discussion may make clearer the viewpoint from which it was written.—C. R. B.

"There are many advantage to be derived from growing a single variety of a given cereal in any particular community. It is also fully apparent that there are climatic and economic factors which may make it desirable or even necessary to grow more than one variety of a cereal, as, for instance, a spring and a winter wheat, on a single farm. This phase may be neglected here in order to place heavy emphasis on the opposite aspect" (p. 172).

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[2] Ball, Carleton R., Community Growing of Crop Varieties, Jour. Am. Soc. Agron., 5: 165–176, 1913.

ON THE PLANS OF FERTILIZER EXPERIMENTS.

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At the present time there are a great many field experiments conducted to determine the relative effectiveness of different fertilizers. While the objects of these experiments are similar, the plans on which they are conducted vary somewhat with different investigators. Some investigators are following the most approved methods for such tests, while others are following plans that do not yield the desired conclusions with scientific accuracy. If all the field tests of a similar nature were conducted according to the best methods, there would probably be fewer discordant conclusions regarding the effectiveness of different fertilizers.

It therefore seems that it might be expedient to adopt standard plans for certain classes of field tests with fertilizers. A standard plan for determining the effectiveness of different phosphates, for instance, should, with certain modifications, serve equally well for all localities and crops. An examination of field experiments which are designed to determine the relative effectiveness of different fertilizers furnishing the same element shows that there is in many cases need for such a standardization of plans.

Take, for instance, the Maryland[1] experiment on the relative effectiveness of different phosphates. In this experiment the ten different phosphates which were compared, were all applied at the rate of 150 lbs. of P_2O_5 per acre. Only one application of potash was made to the plots in the course of the experiment and some plots received no nitrogen at all, while other plots received only the nitrogen of a cover crop turned under. Hence no provision was made for maintaining the phosphoric acid as the limiting factor in the yield. There were no plots which had phosphates applied at a greater or less rate than 150 lbs. of P_2O_5 per acre. It is stated that:

> "The quantities of phosphoric acid applied in these tests are rather more than would be found economical in practice; but it was thought best in planning the experiment to have an excess present and so endeavor to make the results more pronounced, than to attempt to conduct the work simply on the basis of profits. The object of the investigations was to establish prin-

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[1] Md. Expt. Sta. Bulls. Nos. 68 and 114.

ciples connected with the use of phosphates rather than the limits of the soil requirements."

After conducting the experiment ten years one of the conclusions drawn from the results is that: "Insoluble phosphates produced a slightly higher total average than soluble phosphates and at about one half the cost."

Now this is a quantitative experiment in its object, but not in its plan. Although some conclusions of a qualitative nature can be drawn from the experiment as planned, it seems hardly justifiable to draw conclusions regarding the relative effectiveness of the different forms of phosphoric acid. It is evident, for example, that the insoluble phosphates produced a certain increase in yield; but how can we compare the relative effectiveness of the different forms of phosphoric acid if some of them were applied in excess of the soil's requirements? Moreover, how can we tell but what the more available phosphates were applied in excess of the soil's requirements, since there were no plots with more or less than 150 lbs. of P_2O_5 per acre? Suppose 75 or 50 lbs. of P_2O_5 from superphosphate would have produced the same increase as 150 lbs. of P_2O_5, then the superphosphate would have appeared two or three times as effective as it does. If any of the phosphates were applied in excess, phosphates of unequal availability might appear equal and phosphates differing greatly in availability might appear to differ but slightly. Of course if none of the phosphates were applied in excess of the crop's requirements the conclusions are valid. But if the conclusions were to be demonstrated with anything approaching scientific certainty the plan should have included plots receiving more and less than 150 lbs. of P_2O_5 per acre.

It seems that the plans of many of the field experiments on the availability of different phosphates are open to the same objections as the Maryland experiment. As a rule only one quantity of phosphoric acid is applied, and no plots are planned to show whether under conditions of the experiments this quantity of phosphoric acid is the limiting factor in the crop yield. Of course the smaller the quantities of phosphoric acid applied and the greater the crop increases produced, the greater is the probability that the phosphoric acid is below the maximum amount. On this ground it seems probable that the 320 lbs. of acid phosphate used in the Ohio experiment on the availability of raw rock phosphate do not furnish phosphoric acid in excess of the crop's requirements; proof of this is lacking, however.

This error in failing to determine whether or not the fertilizers compared are present in excess, is less common in pot experiments than in field experiments. It sometimes occurs, however, as can be seen in experiments 13 and 14 of bulletin 250 of the New Jersey Experiment Station.

In experiment 13 the availabilities of Newberry's citrate-soluble phosphates are compared with acid phosphate. The test was conducted in pots holding 20 pounds of white sand. All pots received 2 grams of nitrate of soda and 2 grams of potassium sulphate. Two pots received no phosphate and the remaining pots received either 5 grams of the Newberry's phosphates, 5 grams of acid phosphate or 5 grams of Thomas slag. Twenty barley plants were grown per pot. The two pots receiving no phosphate yielded an average of 4.2 grams dry matter. The acid phosphate and Thomas slag pots yielded 11.6 grams and 12.5 grams of dry matter respectively, while the three Newberry's phosphates yield 11.5, 11.0, and 10.1 grams. The conclusion is drawn that, "There is little difference in the availability of the different forms of phosphate under consideration."

Now does the plan of the experiment warrant drawing such a conclusion? Since there were no pots receiving more or less than 5 grams of the phosphate materials we do not know but what one or all the phosphates were applied in excess. In fact an examination of the results and plan of the experiment would lead one to suppose that the phosphates were all in excess and that nitrogen was the limiting factor in the plant growth. Only about .3 gram of nitrogen was applied to the pots and about .7 gram of P_2O_5, while the plant requires much more nitrogen than phosphoric acid. Also the yields of the pots receiving the different phosphates were all practically the same, the differences being hardly greater than the multiple of the probable error. We should at least expect a difference between the Thomas slag and acid phosphate pots in a short-time experiment on a white sand, since acid phosphate is generally considered more available under such conditions.

Experiment 14 in the same bulletin is on "The Availability of Ground Phosphate Rock as Compared with Acid Phosphate." The soil, number of plants, and general fertilizers applied were the same as in experiment 13, except that 50 c.c. of soil infusion and no nitrate of soda was applied. The phosphate pots received respectively 4 grams of acid phosphate, 4 and 8 grams of ground rock, and 4 and 8 grams of Germofort phosphate. It is stated that, "The yields given where the ground untreated rock was used compare very favorably with the yield from pots where acid phosphate was used, the average from the latter being 12.1 grams and for all the ground rock samples

12.8 grams." If this statement is intended to imply that the acid phosphate and ground rock were of practically equal availability under the conditions of the experiment, it is unwarranted as the experiment is open to the same objections as the previous one.

The general fault in these experiments lies in not taking into consideration the law of minimum. If the effectiveness of different forms of the same element are to be compared, this element must be the controlling factor in plant growth under the conditions of the experiment and must be present in minimum. While this principle is, of course, universally recognized, it is not universally taken account of in the plans of fertilizer experiments.

It is not intended to recapitulate here the principles which, by common sense and the experience of many investigators. we know should govern the planning and execution of fertilizer tests. While these principles are generally known, the fact that they are not always observed, is an argument for a standardization of plans for certain field tests. In adopting a standard plan, certain more recent investigations on the law of minimum should not be disregarded.

Since the plans of fertilizer experiments are dependent on the law of minimum the question whether Liebig's or Mitscherlich's formulation of this law is correct, is of more than theoretical importance. If Mitscherlich's idea of the law of minimum is correct, practically all field experiments on the relative availability of fertilizers have been subject to a certain amount of error. According to Mitscherlich's conception of the law of minimum, the increase in plant growth with unit increase of the element in minimum is proportional to the decrement from the maximum,[2] while according to Liebig's conception of this law the increase in plant growth is directly proportional to the increase of the element in minimum. The difference between the two laws can be seen graphically. That is, according to Liebig's, or old law of minimum, each unit increase of the element, or factor, in minimum produces the same unit increase in growth, while according to the Mitscherlich law the first unit increase of the element in minimum produces a greater unit increase in growth than the subsequent increases of the element.

If the Mitscherlich law is correct, the method heretofore used of comparing the relative availabilities of different fertilizers by the relative increased yields produced by a certain amount of fertilizer is not quite accurate. If P_2O_5 is in the minimum by 100 pounds per acre, a 50-pound application of P_2O_5 would produce more than two thirds the increase of a 75-pound application of P_2O_5 and more than one half the increase of a 100-pound application.

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[2] See Mitscherlich, "Bodenkunde" (Berlin, 1913) and Landw. Versuchsstat., 75: 231.

Until we have more data on the subject it would be premature to revise the plans of field experiments to conform with Mitscherlich's law of minimum. The law seems well substantiated, however, by Mitscherlich's data as well as by certain other considerations. Liebscher apparently had the same fundamental idea as Mitscherlich although he did not develop it. As a result of a study of the fertilizer requirements of plants he stated in 1895: "Die Pflanze kann den im minimum vorhandenen Produktionsfaktor zu um so grösserer Produktion benutzen, je mehr die anderen Produktionsfaktoren sich für sie im Optimum befinden."[3] The fact that the percentage of a fertilizing element in a plant often increases with increasing amounts of fertilizer before the fertilizer applied is in excess, also makes it probable that the rate of increased growth should take the form of a curve rather than a straight line.[4]

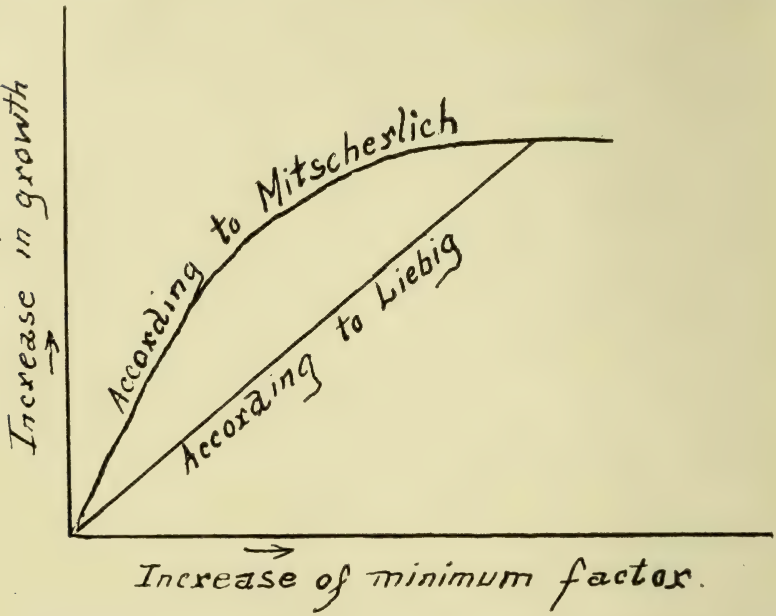

FIG. 2.—Diagram illustrating the laws of Liebig and Mitscherlich.

With the variable conditions that field experiments are subject to, it is doubtful if the increased growth caused by fertilizers will often follow exactly the theoretical rate. For this reason it seems that a plan of a fertilizer test somewhat as follows would give results which are more accurate than many of the present plans for such experiments and yet afford conclusions that are not dependent on theoretical considerations.

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[3] Liebscher, Journ. f. Landw., 43: 216, 1895.

[4] Jordan, W. H., N. Y. Agri. Expt. Sta. (Geneva) Bull. 360.

In a test of the availability of different forms of nitrogen, for instance, all the plots should receive phosphoric acid and potash in considerable excess. The standard, or most available form of nitrogen, as nitrate of soda, should be applied in several quantities, say at the rate of 20, 30, 40, 60, and 90 pounds of nitrogen per acre, while all the other forms of nitrogen could be applied at the rate of, say 50 pounds of nitrogen per acre. Then a comparison of the yields would show whether 20, 30, 40, or 60 pounds of the standard form of nitrogen were required to give the same yield as the 50 pounds of the unknown form of nitrogen. The ratio of the quantities giving the same yields would give the relative availabilities.

Such a plan would show whether or not the quantities of fertilizers tested were in minimum and thus guard against errors which sometimes occur. The conclusions would also be valid whether Liebig's or Mitscherlich's law of minimum is the correct one. The results of such a test would probably instill a healthy discrimination, or what Professor James called "tough-mindedness," in the conclusions. The regularity with which the yield increased with increasing amounts of the standard fertilizer would show about what order of differences between the different fertilizers were significent.

The objection to this plan is that it multiplies the number of plots and so necessitates a larger area for the experiment. It seems better, however, to increase the number of different treatments by two or three and so increase the accuracy of the whole work. If it is impracticable to test four or five quantities of the standard, or most available fertilizer, at least two quantities should be used, so that it will be evident that the smaller quantity (which can be used for the comparison) is not present in excess of the crop's requirements.

The point raised by Mr. Gile is well taken. It was partially recognized in the plan of the Pennsylvania experiments 30 odd years ago, and the Ohio experiments were readjusted in partial conformity with it 15 years ago. Professor Hall calls attention to it in his book, "Fertilizers and Manures," pages 282–283, under the head of "The law of diminishing returns." This law works out practically the same curves as those drawn by Mr. Gile. While, therefore, it is not a new thing, it is often well to emphasize that which is comparatively well known.—C. E. T.

BRIEFER ARTICLES.

BASING ALFALFA YIELDS ON GREEN WEIGHTS.

In field experiments with alfalfa it is customary to determine and report the yields as "cured hay." The term "cured hay" is indefinite. It is customary in many sections to weigh the hay when the plant stems are sufficiently dry to break readily and without exuding water. Usually when the hay reaches this degree of dryness it is considered "cured hay." Alfalfa is cured in cocks, and great variation in the degree of dryness reached at a given time results from the different sizes of cocks, from variations in the moisture content of the surface soil beneath the cocks and from various other causes. In addition to these causes of variation, the personal equation is important, since the estimate of whether or not the hay is "cured" rests almost entirely on the personal judgment of the field man.

A further disadvantage of using "cured hay" weights is that the alfalfa is subjected, while curing, to serious damage from various causes. Such agencies as wind, rain, stray live stock, etc., frequently destroy the results of experiments or seriously impair their value. Any reliable method which would reduce the danger of damage from these causes is worth consideration.

It seems clear that the use of green weight determinations as a basis for determining yield differences might be preferable to "cured hay" determinations, if it is found that the green weight of alfalfa is reasonably constant under different conditions. Some determinations made on irrigated alfalfa at the Bureau of Plant Industry field stations at Huntley, Montana, and Fallon, Nevada, in 1913, will throw some light on the question of the reliability of the method of using green weights, and perhaps suggest further investigation.

Determinations at Huntley.[1]

At Huntley, 28 ten-pound samples of green alfalfa were taken on 12 different dates from June 14 to September 12. Six of these samples were taken from the first crop on three different dates; 11 were taken from the second crop on four different dates, and 11 were taken from the third crop on five different dates. Most of the samples in each crop were taken at intervals of five days. The samples were placed in burlap bags and weighed as soon as cut, and then hung up in a dry, well ventilated place, and weighed periodically until they ceased to lose weight. It required 2 to 4 weeks for the samples to become dry.

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[1] These determinations were made by Mr. Dan Hansen, superintendent of the Huntley Experiment Farm.

At the time each sample was taken, the length of the basal shoots and the stage of the bloom of the plants were estimated. In Table I the results obtained from the determinations made on the 28 samples are classified first on the basis of crop; second, on the basis of length of basal shoots; and, third, on the basis of flowering stage. The loss in weight is expressed as a percentage of the green weight. The third column under "Loss in Weight" is given to show the range of variation in the weights of samples of the same class.

TABLE I.—*Loss in Weight of 28 Samples of Alfalfa at the Huntley Experiment Farm, 1913.*

Classification	No. of Samples	Loss in Weight, Percent			
		Highest	Lowest	Range	Average
First crop	6	80.6	74.8	5.8	76.8
Second crop	11	80.0	70.6	9.4	76.2
Third crop	11	80.0	70.0	10.0	76.5
Three crops	28	80.6	70.0	10.6	76.5
Length of basal shoots:					
½ inch	3	80.0	73.6	6.4	75.9
1 inch	6	78.4	75.4	3.0	76.8
2 inches	9	80.6	70.0	10.6	77.0
3 inches	6	78.4	73.6	4.8	76.6
4 inches	4	77.2	70.6	6.6	74.6
All samples	28	80.6	70.0	10.6	76.5
Flowering stage:					
Trace of bloom	3	80.0	73.6	6.4	75.9
1/20 bloom	8	80.0	72.4	7.6	76.6
1/10 bloom	7	80.6	70.0	10.6	77.3
1/5 bloom	4	78.4	77.2	1.2	77.6
1/4 bloom	1	73.6	73.6	....	73.6
1/3 bloom	1	70.6	70.6	....	70.6
1/2 bloom	2	76.0	76.0	....	76.0
Full bloom	2	76.0	74.8	1.2	75.4
All samples	28	80.6	70.0	10.6	76.5

DETERMINATIONS AT FALLON.[2]

At Fallon, shrinkage determinations were made on 30 samples—15 from the first crop and 15 from the second. These samples were taken on 10 different dates, from June 2 to September 11, three samples being taken on each sampling date. The samplings were made at intervals of one week in the first crop and two weeks in the second crop. The first sampling in each crop was made when the first blooms appeared. The samples were dried in cloth bags hung in the open air and weighed periodically until they ceased to lose weight. The drying required from 2 to 4 weeks. In Table 2 are reported the results obtained from the determinations on the 30 samples. The length of basal shoots and the stage of bloom were not noted at each sampling time, as they were at Huntley, so that the same classification cannot be given.

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[2] These determinations were made by Mr. F. B. Headley, superintendent of the Truckee-Carson Experiment Farm.

TABLE 2.—*Loss in Weight of 30 Samples of Alfalfa at the Truckee-Carson Experiment Farm, 1913*

Classification	Number of Samples	Loss in Weight, Percent			
		Highest	Lowest	Range	Average
First crop	15	81.6	73.7	7.9	77.1
Second crop	15	79.2	71.7	7.5	76.0
1st and 2d crops	30	81.6	71.7	9.9	76.5
First crop:					
Cut June 2	3	81.6	77.3	4.3	80.0
June 9	3	80.5	79.0	1.5	79.7
June 18	3	76.2	74.7	1.5	75.3
June 24	3	77.3	75.0	2.3	76.4
July 5	3	75.3	73.7	1.6	74.3
All samples	15	81.6	73.7	7.9	77.1
Second crop:					
Cut July 16	3	79.2	78.2	1.0	78.7
July 30	3	77.7	76.3	1.4	77.2
Aug. 13	3	75.6	71.7	3.9	73.6
Aug. 29	3	77.7	73.6	4.1	75.7
Sept. 11	3	75.5	74.0	1.5	74.8
All samples	15	79.2	71.7	7.5	76.0

SUMMARY.

1. Of the 28 samples taken on 12 different dates at Huntley the average loss in weight was 76.5 percent of the green weight. Of the 30 samples taken on 10 different dates at Fallon, the average loss in weight was exactly the same as at Huntley.

2. The highest loss was 81.6 percent at Fallon and 80.6 percent at Huntley; the lowest at Fallon was 71.7 percent and at Huntley 70.0 percent; the extreme range was 10.6 percent at Huntley and 9.9 percent at Fallon.

3. The results fail to show any consistent significant differences in the loss in weight of samples cut on different dates or at different

stages of growth; that is, when the range of variation in samples cut on the same date or at the same stage of growth is considered it is seen that the variation in samples cut on different dates and at different stages of growth is not large enough to be considered significant.

4. While the results reported above are not sufficient to warrant a conclusion as to the relative desirability of using green weights and of using "cured hay" weights, the losses in percent of green weight under rather diverse conditions were sufficiently constant to suggest the advisability of further investigation.—F. D. FARRELL, Office of Western Irrigation Agriculture, U. S. Department of Agriculture.

AGRONOMIC AFFAIRS.

A THOUGHT FOR THE NEW YEAR.

With the present issue the JOURNAL begins the second year of its publication. The success that has attended the first year's issuance as a quarterly is ample justification for making the JOURNAL a bimonthly. The standard that has been attained is high and gives encouragement to the workers who have lofty ideals of the possibilities that lie in the subject. Much, however, remains to be accomplished to make agronomy thoroughly scientific in achievement as well as in aim.

In the already vast amount of agronomic literature, there is much that is vague and unsatisfactory. Some of this has already become obsolete or discredited in the light of recent research, and much more is destined to the same fate.

In a broad way this may be looked upon as the necessary result of a proper scientific scepticism and the application of a more rigorous logic to the interpretation of known facts. Too many of the statements of earlier writers are little more than individual judgments based on observations and without adequate basis of critically determined facts. In other words, they are expressions of opinion, and the spirit of the modern agronomist approaches that of the sceptical philosopher whose dictum was "opinion be damned."

It is undoubtedly true that most American writings on agronomic subjects have been mainly dissertations on the culture of crops and the handling of soils based on experience and on field experiments. As such they have, as a rule, been safe and sane treatises for practical use. When, however, the reasons for special treatment of the soil or crops were discussed, this has invariably been done on the basis of theories the truth of which has been accepted almost without question.

Practically it matters very little just how tillage or lime or fertilizers operate in affecting yields after the facts have been empirically ascertained; or why some plants are adapted to different conditions than others. Theoretically, however, these matters lie at the very foundation of agronomy, and the real progress of the science depends on how much our knowledge of these broad subjects is increased. The very matters that need investigation most are obscured by the constant use of the phraseology which tacitly accepts as fact what is unproven theory. It is very doubtful if the farmer is at all helped by the use of such expressions as "lime sweetens the soil," "cabbage is a gross feeder," etc.

It is certain that by the use of such phrases agronomists form the habit of using loose logic. For a New Year's resolution let us all try to avoid in our writings, both technical and popular, expressions that are not founded on determined facts. It is just as easy to do this as to resort to rhetorically good but scientifically bad statements—C. V. P.

SPECIAL MEETING AT DALLAS, TEXAS.

A call for a special meeting to be held at Dallas, Texas, on February 18, in connection with the Sixth National Corn Exposition, was issued early in January and also published in the JOURNAL. The meeting will be held at the fair grounds and the session will open at 1:30 in the afternoon. An evening session will be held if necessary.

The following titles have been offered:

1. The Use and Management of Check Plats in Soil Fertility Investigations. A. T. Wiancko.
2. Mendelian Inheritance in Wheat, Oat and Barley Hybrids (illustrated). E. F. Gaines.
3. Agronomic Instruction in Agricultural High Schools. J. C. Robert.
4. A Tentative Score Card for Judging Seed Cotton, Cotton Burrs and Cotton Stalks, in Cotton shows. A. M. Ferguson.
5. Moisture Relations of Texas Soils. G. S. Fraps.
6. Breeding, Testing, and Distributing Improved Seed Grain in North Dakota. W. R. Porter.
7. A New Method of Growing Corn. C. C. Cunningham.

MEMBERSHIP CHANGES.

New Members.

The addition of 24 new members to the rolls so early in the new year is very gratifying, as giving evidence that the Society is of service to agronomy. 349 members, less one resigned, and plus 24 new members, make a present total of 372 members.

Bear, Firman E., Agricultural College, Univ. of W. Va., Morgantown, W. Va.
Bonnett, Robert K., Agricultural College, Manhattan, Kans.
Burr, W. W., Bu. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Carr, Ralph H., 24 N. Salsbury Street, Lafayette, Indiana.
Cassel, Charles E., Tribune Substation, Tribune, Kans.
Dunton, Leila, Agricultural College, Manhattan, Kans.
Grace, O. J., Akron Experiment Farm, Akron, Colo.
Grimes, W. E., Agricultural College, Manhattan, Kans.
Hanger, W. E., Hyattsville, Md.
Hudelson, R. R., Experiment Station, Columbia, Mo.
Johnson, F. W., Agricultural College, Manhattan, Kans.
Kelley, W. P., U. S. Experiment Station, Honolulu, Hawaii.
La Tourrette, Lyman L., Experiment Station, Manhattan, Kans.
McNeely, L. R., State College, New Mexico.
Millar, C. E., Agricultural College, Manhattan, Kans.
Miller, Edwin C., Dept. of Botany, Agricultural College, Manhattan, Kans.
Schoonover, Warren R., Agricultural Experiment Station, Urbana, Ill.
Sieglinger, J. B., Agricultural College, Manhattan, Kans.
Southwick, Benjamin G., Experiment Station, Storrs, Conn.
Thompson, G. E., Agricultural College, Manhattan, Kans.
Throckmorton, R. I., Dept. Agronomy, Agricultural College, Manhattan, Kans.
Wehrle, L. P., Agricultural College, Manhattan, Kans.
Wilson, Bruce S., Experiment Station, Manhattan, Kans.
Zerban, F. W., 903 Whitney Central Bank Bldg., New Orleans, La.

Members Resigned.

Jodidi, Samuel L.

Addresses Changed.

Krause, Franz E. F., Renville, Minn.
Krechov, William, Agricultural College, Nicolaevsky-Gorodok, Saratovsky Government, Russia.
Zook, L. L., 1236 South 15th Street, Lincoln, Nebr.

COMING EVENTS.

Under this caption it is proposed to keep a standing schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

American Society of Agronomy.

Special Meeting, Dallas, Texas, during the National Corn Exposition, February 18, 1914.

American Association for the Advancement of Science.

Philadelphia, Pa., Convocation Week, 1914–15.

American Chemical Society.

Spring Meeting, Cincinnati, Ohio, April 8–11, 1914.

American Genetic Association (Plant Section).

Dallas, Texas, February 20–21, 1914.

American Society of Milling and Baking Technologists.

Annual Meeting, Washington, D. C., November, 1914 (in connection with the Association of Official Agricultural Chemists).

Association of Official Agricultural Chemists.

Annual Meeting, Washington, D. C., November, 1914.

National Corn Exposition.

Dallas, Texas, February 10–24, 1914.

LOCAL SECTIONS.

Cornell University and Experiment Station.

President, Millard A. Klein.
Secretary,——————————.

Kansas Agricultural College and Experiment Station.

President, W. M. Jardine.
Secretary-Treasurer, C. C. Cunningham.

U. S. Department of Agriculture.

President, W. W. Burr.
Secretary-Treasurer, F. D. Farrell.

JOURNAL

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NITROGEN AND ORGANIC MATTER IN DRY–FARM SOILS.

Robert Stewart and C. T. Hirst.

(Contribution from the Chemical Laboratory, Utah Experiment Station, Logan, Utah.)

Introduction.

Dry farming has now been successfully practiced in some portions of the state of Utah for over fifty years and, contrary to predictions, the yield of wheat has not materially decreased. In most wheat-growing regions such as the Great Plains area the continuous growing of wheat on the same land causes a rapid decrease in the crop-producing power of the soil. This decrease in the producing power of the soil has been associated by Snyder[1] and Ladd[2] with a loss in the nitrogen and humus content of the soil. The summer fallow has been apparently more destructive of the organic matter and nitrogen than has continuous cropping alone. This loss has been brought about, according to these investigators, by favorable conditions for rapid oxidation of the organic matter of the soil with the resultant loss of nitrogen by denitrification. In 1907, an examination of the cultivated and virgin soils of the Cache Valley, Utah, was made to ascertain the effect of continuous cropping and summer fallowing on the nitrogen and humus content of the soil. The results obtained have been published[3] and are indicated in Table 1.

These results are just opposite to those found by earlier investigators. The cropping of the dry farm soil in Utah for great lengths of time was not accompanied by a marked decrease in the nitrogen and humus content of the *surface* foot of the cultivated soil.

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[1] Min. Expt. Sta. Buls. 30, 41, 53, 65, 70, 94.

[2] N. Dak. Expt. Sta. Buls. 24, 32, 35, 47.

[3] Stewart, Utah Experiment Station Bulletin No. 109, 1910.

TABLE 1.—*Summary of Determinations of Nitrogen and Humus in the Cache Valley, Utah, Organic Nitrogen and Humus Reported in Percentages of Dry Soil and Nitric Nitrogen as Parts per Million.*

Crop.	Depth of Sample.	No. of Analysis.	Organic Nitrogen.	Nitric Nitrogen.	Humus.
Wheat........	0–12	27	0.2055	0.80	2.67
Virgin........	0–12	22	0.1984	1.04	2.45
Alfalfa........	0–12	11	0.2009	1.74	2.27
Wheat........	12–24	24	0.1466	0.76	2.45
Virgin........	12–24	19	0.1823	1.38	1.99
Alfalfa........	12–24	11	0.1604	0.60	1.73

During the past five years this investigation has been extended so as to include all the dry-farming soils in the state which have been cropped for over ten years. The results obtained on the Nephi Experimental Farm have already been discussed[4] and are indicated in Table 2.

TABLE 2.—*Nitrogen, Humus and Organic Carbon in Cultivated and Virgin Soil of the Nephi Experiment Farm.*

Results Reported in Percentages of Dry Soil.

First Foot.

Treatment.	Nitrogen.	Humus.[5]	Organic Carbon.[6]
Virgin soil......................	0.116	1.34	0.315
Continuous cropped............	0.117	1.39	0.558
Alternate cropped and fallow....	0.108	1.01	0.611
Alfalfa........................	0.110	1.33	0.599

Second Foot.

Treatment.	Nitrogen.	Humus.[5]	Organic Carbon.[6]
Virgin soil......................	0.103	0.89	0.436
Continuous cropped............	0.092	0.91	0.477
Alternate cropped and fallow....	0.065	0.78	0.440
Alfalfa........................	0.095	1.38	0.392

These results clearly indicate that the cultivation of the soils in the Cache Valley and on the Nephi Experimental Farm are not accompanied by any marked decrease in the nitrogen and humus content of the surface soil. The results obtained, therefore, by the continuation of this investigation to other parts of the state cannot but be of interest to those studying the problem. It should be carefully noted, however, that in all of our published results there is shown a loss of nitrogen from the *second* foot of the cultivated soil, as compared with the second foot of adjacent virgin soil.

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[4] Stewart, Science, Vol. XXXIV, pp. 248–250, 1911.

[5] By method of Mooers and Hampton, Jour. Am. Chem. Soc., 30: 805, 1908.

[6] By method of Pettit and Schaub, Jour. Am. Chem. Soc., 26: 1640, 1904.

Experimental Part.

The remaining portions of the state which have been cropped to wheat by the dry-farming methods for over ten years are the Bear River Valley, Salt Lake Valley, and the Juab Valley. Samples of the cultivated and the virgin soil were obtained from these sections in 1910 and have been submitted to analysis for carbon and nitrogen. The nitrogen was determined by the regular Kjeldahl method but does not include the nitrogen of nitrates. The humus was determined by the method of official agricultural chemists. The organic carbon was determined by the method of Pettit and Schaub. Since in the latter determination it was necessary to determine the inorganic carbon, this result, calculated as calcium carbonate, has also been reported.

The Bear River Valley Soils.

A soil survey has been made of this section by the Bureau of Soils of the U. S. Department of Agriculture.[7] Information regarding the physical nature of the soil may be obtained from the report. For this study, samples of cultivated and of virgin soil were obtained from seven farms in this section and the individual samples submitted to analysis. The results obtained from the individual analyses all told the same story, so a summary of the results has been obtained by the construction of Table 3. The soil of these several farms has been cultivated for ten to thirty-two years.

An examination of the results recorded in this table show that there is practically no difference in the organic carbon and nitrogen content of the surface foot of the cultivated and adjacent virgin soil.

Table 3.—*Carbon and Nitrogen Content of Dry-farm Soils, Bear River Valley, Utah.*

	First Foot.		Second Foot.		Third Foot.	
	Cultivated.	Virgin.	Cultivated.	Virgin.	Cultivated.	Virgin.
Number of tests.....	7	7	7	7	3	2
Calcium carbonate...	8.52	1.31	10.12	6.11	16.79	15.13
Organic carbon......	1.27	1.31	0.79	0.83	0.69	0.43
Organic nitrogen.....	0.101	0.105	0.0632	0.0669	0.0498	0.0429

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[7] Soil Survey of the Bear River Area. Sixth report of the Bureau of Soils.

The Salt Lake Valley Soils.

The dry farm soils of Davis County are very sandy in character. Most of the dry farming is conducted on the sand ridge lying between Ogden and Salt Lake City. The land is pretty well utilized, thus rendering it difficult to secure fair representative samples of virgin soil. Such results, however, as were obtained do not show any decrease in the nitrogen and carbon content of the soil but rather a marked increase in these constituents, as will be noted in Table 4.

TABLE 4.—*Summary of Carbon and Nitrogen Content of Cultivated and Adjacent Virgin Soil, Davis County, Utah.*

	First Foot.		Second Foot.		Third Foot.	
	Cultivated.	Virgin.	Cultivated.	Virgin.	Cultivated.	Virgin.
Number of tests.....	15	3	13	3	11	3
Calcium carbonate...	4.16	2.46	8.34	11.45	7.06	20.65
Organic carbon......	1.46	0.96	0.93	0.81	0.73	0.76
Organic nitrogen.....	0.1141	0.0763	0.0801	0.0637	0.0571	0.0545
Humus.............	1.23	1.30	1.21	1.08	1.04	1.30

The Juab Valley Soils.

The Nephi experimental dry farm is located in Juab county. Some results of determinations of nitrogen and humus in these soils have already been published. Complete results are reported in Table 5.

TABLE 5.—*Summary of the Carbon and Nitrogen Content in Dry-farm Soils, Nephi, Juab County, Utah.*

	First Foot.		Second Foot.		Third Foot.	
	Cultivated.	Virgin.	Cultivated.	Virgin.	Cultivated.	Virgin.
Number of tests.....	12	11	12	9	11	10
Calcium carbonate...	12.36	12.34	20.46	20.52	22.33	24.85
Organic carbon......	1.16	1.23	0.88	0.99	0.84	0.87
Organic nitrogen.....	0.103	0.105	0.077	0.063	0.056	0.059
Humus.............	1.19	1.67	1.22	1.03	0.99	0.82

The very uniform results reported for the calcium carbonate may be taken as an indication of the uniform character of the soil. The high amount of calcium carbonate is itself very remarkable. The results for organic carbon and nitrogen in the cultivated and virgin soil agree as closely as would duplicate results of the same sample, indicating quite clearly that there has not been a marked loss of nitrogen and organic carbon from the soil.

Discussion of Results.

For convenience of observation, these results are summarized in Table 6. These results obtained on the highly carbonated soils of Utah clearly indicate that, contrary to the established teaching on the subject, there is not a marked loss in nitrogen and humus of the cultivated surface soil.

TABLE 6.—*Summary of the Organic Carbon and Nitrogen Content of the Dry-farm Soils of Utah.*

First Foot.

	Box Elder Co.		Davis Co.		Juab Co.	
	Cultivated.	Adjacent Virgin.	Cultivated.	Adjacent Virgin.	Cultivated.	Adjacent Virgin.
No. of determinations	7	7	15	3	12	11
Calcium carbonate...	8.52	1.31	4.16	2.46	12.36	12.34
Organic carbon......	1.27	1.31	1.46	0.96	1.16	1.23
Organic nitrogen.....	0.101	0.105	0.1141	0.0763	0.103	0.105
Humus............	.....	.....	1.30	1.21	1.19	1.67

Second Foot.

	Box Elder Co.		Davis Co.		Juab Co.	
	Cultivated.	Adjacent Virgin.	Cultivated.	Adjacent Virgin.	Cultivated.	Adjacent Virgin.
No. of determinations	7	7	13	3	12	9
Calcium carbonate...	10.12	6.11	8.34	11.45	20.46	20.52
Organic carbon......	0.79	0.83	0.93	0.81	0.88	0.99
Organic nitrogen.....	0.0632	0.0669	0.0801	0.0637	0.077	0.063
Humus............	.....	.....	1.21	1.08	1.22	1.03

Third Foot.

	Box Elder Co.		Davis Co.		Juab Co.	
	Cultivated.	Adjacent Virgin.	Cultivated.	Adjacent Virgin.	Cultivated.	Adjacent Virgin.
No. of determinations	7	7	11	3	11	10
Calcium carbonate...	16.79	15.13	7.06	20.65	22.33	24.85
Organic carbon......	0.69	1.68	0.73	0.76	0.84	0.87
Organic nitrogen.....	0.0498	0.0429	0.0571	0.0545	0.056	0.059
Humus............	.....	.....	1.04	1.30	0.99	0.82

The earlier work of Snyder,[8] Ladd[9] and Alway[10] showed a marked loss of nitrogen and humus. Snyder's samples were taken to a depth of nine inches; Ladd's samples were taken to a depth of ten inches, while Alway's samples were taken to a depth of six inches. In every case, according to these investigators, the noted loss of nitrogen and humus occurred in *the surface cultivated soil.* Snyder is strongly of the opinion that the loss was due to denitrification. Alway, however, says "The greatest losses of organic matter, nitrogen and humus have been caused either by the washing or by the blowing away of the

[8] Minn. Exp. Sta. Buls. 30, 41, 53, 65, 70, 94.

[9] N. Dak. Exp. Sta. Buls. 24, 32, 35, 47.

[10] Neb. Exp. Sta. Bul. 111.

surface soil." In our former work[11] we did not find any such marked loss of nitrogen and humus from the surface soil, which we account for by the assumption that the deeper-rooted plants of the Great Basin Area caused the plant to draw heavily upon the nitrogen supply of the subsoil. More recently Thatcher[12] has investigated this question with reference to the soils of Washington. Thatcher believes that his results confirm the earlier work of Snyder, Ladd and Alway and that they are directly opposite to ours obtained in Utah. It would not be at all surprising if the Washington soil would conform more to those of Nebraska, Minnesota and North Dakota, since Alway's view that the greatest loss is due to erosion is probably the correct explanation. A close examination of Thatcher's results, however, confirms our findings to a remarkable degree, as may be seen by an examination of Table 7, where Thatcher's results have been converted into a little different form to those reported by him. This table shows the relative amount of the total loss from each depth. The results are expressed both in the form of percentage and pounds per acre.

TABLE 7.—*Distribution of Loss of Nitrogen in Various Depths of Washington Soil.*

Depth of Sample.	Pullman.		Deep Creek.		Almira.	
	Percentage of Total.	Pounds.	Percentage of Total.	Pounds.	Percentage of Total.	Pounds.
1st foot	18	294	29	806	7	42
2d foot	12	196	48	1,334	71	426
3d foot	38	619	12	334	22	132
4th foot	32	521	11	306	...	...
Total	100	1,630	700	2,780	100	600
Nitrogen removed in crop		1,200		900		250

In no case does the loss of nitrogen in the first foot equal the amount removed in the crop. In the Pullman district the loss in the first three feet of soil is less than the amount removed in the crop. The greatest loss of nitrogen occurs in the second or third foot. According to Thatcher the loss of nitrogen in the Washington soils is accounted for by the favorable conditions in the summer fallow for the rapid oxidation of the organic matter in the plowed surface of the soil, with a resultant loss of nitrogen by denitrification. The summer fallow may be favorable for the rapid oxidation of the organic matter near the surface, but it is difficult to conceive why the greatest loss should take place in the second and third feet. It thus appears that Thatcher's results confirm our contention that there is no marked loss of nitrogen in the surface, cultivated, dry-farm soils, and that the loss of nitrogen occurs below the plowed surface soil.

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[11] Stewart, Utah Exp. Station Bul. 109.

[12] Thatcher, Washington Exp. Sta. Bul. 105.

If it be true that the greatest loss of nitrogen and humus occurs below that plowed surface is not the problem of addition of organic matter and nitrogen to the dry farming soil more complicated and difficult than in a humid section? How are we to increase the organic matter and nitrogen contents of the second and third foot by addition to the plowed surface?

It would seem to be clearly indicated that in the dry-farm soils of Utah there is not a marked loss of nitrogen and organic matter of the plowed surface of soil. The reason why such loss is noted elsewhere and not in our soils is due to several factors. The noted loss of nitrogen in other wheat-growing sections in addition to the nitrogen removed in the crop is due, in the opinion of the authors, largely to erosion by the wind. The surface soil, rich in organic matter and nitrogen is removed by erosion, thus allowing the operator to secure a sample of soil containing more of the subsoil and therefore less nitrogen. The virgin soil being in the native sod does not erode like the cultivated soil would. Furthermore, the surface virgin soil in Utah to begin with is low in organic nitrogen and carbon, due to the meager growth of native vegetation. The addition of any organic matter such as straw and weeds tends to neutralize the loss of organic matter by oxidation. Especially is this true when the deep-rooted character of the dry-farm grains is considered. The feeding range of the wheat plant is thus materially increased, allowing it to obtain part of its nitrogen supply from the subsoil.

SUMMARY.

The dry-farm soils of Utah are remarkably well supplied with calcium carbonate, thus rendering the addition of this substance unnecessary even in the very remote future.

The results of the study reported herein, together with those previously reported, do not show any such marked decrease in the nitrogen and humus supply of the surface cultivated dry-farm soils, as has been found by previous investigators.

This is probably due to the deep-rooted character of the wheat plant when grown under dry-farm conditions and to the fact that very *little erosion* takes place by wind or water. In the virgin condition our dry farm soils are very low in nitrogen. The character of the native vegetation is such as to add little organic matter to the soil during the virgin state. The deep-rooted wheat plant secures a portion of its nitrogen from the lower depths of the soil. The plowing under of the straw and stubble tends to maintain the nitrogen content of the surface cultivated soil.

The dry-farm soils of Utah are well supplied with limestone and the mineral elements of plant food, thus making the maintaining of the nitrogen supply the most important part of the soil fertility problem of the dry farm in Utah. It is therefore imperative that the farmer use every means at his command to plow under the straw and stubble. The future may demonstrate the necessity of utilization of a leguminous crop for this purpose.

THE COMPOSITION AND QUALITY OF MEXICAN WHEATS AND WHEAT FLOURS.

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INTRODUCTION.

These investigations were instituted in this laboratory under the writer's direction during the winter of 1912–13 by J. L. Burt, then a special student in the College of Agriculture of this University. Mr. Burt's business interests in Mexico led him to collect these samples in the States of Jalisco and Sonora. He found it necessary to return to Mexico before the work was completed, however, and the remaining tests and analyses were completed so far as was possible and the data tabulated by the writer. The unsettled condition of that Republic has since made correspondence difficult and not as much is known concerning the exact source and character of certain of the samples as is desirable, but it is believed that the data at hand will prove of sufficient interest to justify its publication, even though in a somewhat incomplete manner.

WHEAT GROWING IN JALISCO AND SONORA.

The state of Jalisco borders on the west coast of Mexico, and is one of the group of states ranking highest in wheat production. The map showing graphically the production of wheat in Mexico for 1899–1900, prepared by the Mexican National Commission to the St. Louis Exposition, shows the States of Jalisco, Sonora, Coahuila, Aguascalientes and Michoacan to have produced an average of 100 to 1,000 kilograms per square kilometer, being exceeded in this regard only by Guanajuato, Queretaro, Mexico, and Puebla, which produced an average of 1,000 to 2,572 kilograms per square kilometer.

According to Mr. Burt, the weather in Jalisco is usually hot and dry during April and May and the rains fall during July, August, and September, while in Sonora, which is farther north, June, July, August, and September are hot and dry, the rains beginning at the end of this period of drought. The wheat fields of Jalisco are principally on high plateaus at an elevation of 5,000 to 6,000 feet, while those of Sonora are about 600 to 800 feet above sea level.

The wheat is usually sown from October first to January fifteenth, the date depending on the distribution of the rainfall and the resulting effect upon the physical condition of the soil. Where water is available, the fields are irrigated before plowing and at once seeded. About two months after seeding they are again irrigated, followed by irrigation at intervals of ten to fifteen days until ripe. In other sections irrigation is not practiced. The plants grow slowly during the winter months, although growth is seldom entirely suspended. As the temperature rises in the spring, growth is markedly accelerated, and the harvest usually occurs during April and May. Headers are commonly employed for reaping, and the grain after threshing is handled in sacks.

Characteristics of the Wheat.

The samples examined represented commercial grain such as the millers are obliged to purchase for grinding into flour. In a number of instances these came from large ranches or "haciendas" and illustrate the character of grain just as it comes from the field. The majority of the samples were mixtures of several types or varieties of wheat among which the white types predominate. While an admixture of red kernels was present in a number of samples, no pure samples of a red variety were obtained. These wheats were all what would be classified as "soft wheat" in this country, corresponding in their physical properties more nearly to the wheats of California than to those of any other section. However, the kernels were often hard when cracked between the teeth, due principally to their dry condition rather than to the density of the endosperm.

The samples were comparatively free from weed seeds or other grains, but in many instances contained appreciable quantities of soil. This soil was difficult to remove in preparing the samples for milling, and the flour was accordingly affected by its presence, as will be noted later in this paper. Because of this, the free use of water in washing the grain is necessary to properly prepare it for milling.

Source of the Samples Collected in Jalisco.

Since Mr. Burt's business interests were centered chiefly in Guadalajara, Jalisco, most of the samples were collected in that city and the territory tributary to it. As will be observed from the following list, which gives such information as is in the writer's possession concerning this group of samples, they came, in most instances, from the producing hacienda or ranch, and represented the raw material available to the millers of Guadalajara. Since it is the practice of the latter to mill a "straight" grade flour representing all the edible flour which can be produced from the wheat, a similar procedure was followed in milling these samples in our experimental mill. A number of samples, as has been mentioned, contained appreciable quantities of soil which, owing to a lack of proper wheat washing machinery, was imperfectly separated in preparing them for milling. Consequently, more or less of this soil found its way into the flour, increasing the percentage of ash and lowering the color score. The ratio between the increase in ash and decrease in color was, moreover, not uniform, since those soils which were rich in humus made the flour darker than did those which were low in organic matter. For this reason the low color scores reported should not be interpreted to mean that flour of satisfactory whiteness could not be produced from these wheats were they freed from soil particles.

Source of Wheat Samples Collected in Jalisco.

Sample No.	Source.
1	Coquito, Jalisco.
2	La Vego, Jalisco.
3	Orecucu Gugar.
4	Arnecu.
13	"Corteo" wheat grown under irrigation.
14	Temporal Virio.
15	Hacienda Coma, at Ocatlan.
16	Milling bluestem, source not known.
17	Bogon, under irrigation.
18	Hacienda de Guadalupe, at Poncitlan.
19	Hacienda de Monteleon.
20	Hacienda de Santa Cruz.
21	Senor Antonio Martiz.
22	Hacienda de San Martin, at Jocotepic.
23	Temporal Cortazar.
24	From mill "A," Guadalajara, ready for milling.
25	Hacienda de Salome, at La Barca.
68	Atequiza, Jalisco.

The percentage of flour produced in milling, composition of wheat and straight flour, and results of the baking tests, are given in Table 1. Only partial analyses of wheat and flour were made, the determinations being confined to those which appear to yield results of greatest practical value. The methods employed were those usually followed in this laboratory, a description of which may be found in Minnesota Agricultural Experiment Station Bulletin No. 131. In general, the yields of straight flour produced from these wheats were fairly good.

The percentage of crude protein in both wheat and flour is rather low when compared with the hard wheats of this country. The percentage of wet and dry crude gluten, determined by washing, is correspondingly low. The effect of these low percentages of protein, and consequently of gluten, was observed when the baking tests were made, the loaves in most instances being rather small and dense as compared with those baked from bread flours of this country. The wheats examined resemble in these regards the wheats of California more than those of any other section of the United States and compare unfavorably with the hard red spring wheats of the northern Great Plains Area with which the work of this laboratory is chiefly concerned.

TABLE I.—*Composition of Jalisco Wheats, and Composition and Baking Tests of Straight Flours Produced from Them in the Experimental Roller Mill at the Minnesota Experiment Station.*

Sample Number.	Yield of Straight Flour.	Composition of Wheat.		Composition of Straight Flour.						Baking Tests.		
		Crude Protein.	Ash.	Moisture.	Crude Protein.	Ash.	Acidity.	Crude Gluten.		Loaf Volume.	Water Used.	Color Score.
								Wet.	Dry.			
	per ct.	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*c.c.*	*per ct.*	
1	70.4	11.26	.....	9.36	10.09	.60	.060	29.7	10.20	2,200	57.4	95
2	65.5	10.93	.....	8.84	9.92	.88	.090	29.0	9.44	2,150	53.5	85
3	71.3	9.67	.....	8.89	8.53	.67	.075	30.1	7.48	1,920	54.1	70
4	70.0	10.84	.....	10.78	9.93	.60	.077	29.2	9.31	2,220	53.5	91
13	69.8	9.32	.....	10.58	8.33	.65	.110	26.3	8.01	1,740	52.6	92
14	70.0	10.63	1.55	10.28	9.82	.67	.105	33.4	9.86	2,040	53.2	92
15	68.0	11.24	1.88	10.08	9.97	.68	.105	31.2	10.02	1,960	53.5	76
16	66.3	13.10	1.80	9.09	11.35	.55	.102	38.2	11.20	2,210	55.3	92
17	72.5	10.22	1.87	10.23	8.95	.51	.110	28.3	8.92	1,550	52.9	90
18	69.0	11.08	1.93	10.34	10.09	.96	.110	32.8	9.86	1,940	54.7	55
19	66.6	10.65	2.00	10.82	9.23	.72	.130	28.9	8.87	2,010	53.5	67
20	66.0	11.49	2.06	10.67	10.55	.56	.070	33.3	10.27	2,060	53.5	88
21	69.0	10.64	1.79	10.11	9.20	.58	.110	29.5	9.14	2,010	54.1	80
22	71.0	10.61	1.83	10.26	9.35	.61	.107	31.2	9.47	2,050	56.5	85
23	69.5	11.90	1.74	10.32	10.49	.51	.098	35.8	10.98	2,200	54.1	101
24	70.5	11.32	1.72	10.37	9.83	.52	.108	33.2	10.06	1,930	52.9	99
25	70.0	10.58	1.88	9.48	9.29	.71	.135	28.8	9.44	2,000	52.1	95
68	73.5	11.06	1.99	10.38	9.52	.54	.....	31.8	9.80	2,010	53.5	96
Average	69.4	10.92	1.85	10.05	9.69	.70	.100	31.1	9.57	2,011	53.9	86

TESTS OF THE SECOND SERIES.

Since so many of the straight flours milled from the first group contained pulverized soil, another group of eight samples was obtained from certain of the same haciendas for further study. In addition seven wheat samples were obtained from the three flour mills of Guadalajara. In this paper these mills are designated as "A," "B," and "C," the same designation being employed in connection with Table 3, which shows the composition and quality of the commercial flours which they produced. Mill "A" is a 350-barrel roller mill operated by a Mexican, mill "B" an old 50-barrel roller mill operated by a miller of the same nationality, and mill "C" a 50-barrel roller mill owned and operated by an American. Samples Nos. 1, 2, 15, 18, 19, 20, 22, and 25 recorded in Table 2 were obtained from the same sources as the samples bearing the same numbers in the first lot, the sources of which are given in the list preceding Table 1. The remaining seven samples were drawn at different times from the stream of wheat going to the rolls in the commercial mills, as follows:

Sample Nos.	Mill.
26, 28, and 30	"A"
34, 69, and 70	"B"
71	"C"

In Table 2 are shown the results of the tests and analyses of these samples. All particles of soil were first removed by hand, and high grade middlings or "patent" flours were produced, rather than straight flours as in the first group. The effect of the careful hand cleaning is reflected in the lower percentage of ash, and improved color, although of course these factors were also affected by the

TABLE 2.—*Tests and Analyses of Jalisco Wheats, and Patent Flours Produced from Them in the Experimental Mill.*

Sample Number.	Milling Tests.		Composition of Patent Flour.						Baking Tests of Patent Flour.		
	Total Flour.	Patent Flour.	Moisture.	Crude Protein.	Ash.	Acidity.	Crude Gluten. Wet.	Crude Gluten. Dry.	Loaf Volume.	Water Used.	Color Score
	per ct.	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*c.c.*	*per ct.*	
1	69.1	70.9	9.57	10.33	.44	.085	35.6	10.95	2,200	56.8	97
2	68.1	67.7	9.89	9.54	.49	.095	31.5	9.90	2,140	56.0	95
15	68.7	72.2	10.06	9.67	.50	.087	30.8	10.40	2,230	56.0	96
18	66.5	69.8	10.26	9.57	.55	.130	27.9	9.46	1,950	54.8	96
19	66.4	74.0	10.28	9.06	.54	.110	27.6	9.15	2,000	56.8	98
20	69.2	73.8	10.43	9.93	.44	.075	32.1	10.04	2,240	55.2	99
22	69.8	70.8	10.60	9.00	.50	.100	30.1	9.96	2,230	56.0	98
25	70.1	72.0	10.43	10.05	.47	.070	33.6	10.52	2,080	55.6	97
26	69.8	64.5	10.95	9.98	.43	.065	35.2	10.64	2,120	56.0	96
28	72.3	72.9	10.91	10.09	.47	.085	33.5	10.06	2,160	55.6	99
30	67.7	66.9	10.50	11.11	.41	.070	39.2	11.22	2,050	56.8	100
34	70.1	66.9	10.70	9.83	.45	.080	35.3	10.12	2,260	57.6	97
69	71.6	72.5	10.12	9.61	.53	.085	31.6	10.06	2,080	57.3	96
70	71.0	70.9	10.14	9.85	.47	......	34.0	10.59	2,150	57.2	98
71	68.4	61.1	10.17	10.07	.....	......	28.9	9.05	2,160	58.4	97
Average	69.4	69.8	10.33	9.85	.48	.087	32.5	10.14	2,137	56.4	97.3

elimination of the lower or "clear" grade. An effort was made in each instance to produce as nearly 70 percent of the total flour as patent as possible, the actual percentage of the total flour represented in this grade being shown, as well as the percentage of total flour produced. The analyses and tests of the patent flours showed them to be low in protein and crude gluten. They also yielded loaves of relatively small volume, although some improvement in these regards was shown over the first group of Jalisco wheats tested.

Composition and Quality of Wheat Samples from Sonora.

Five samples of wheat grown in the vicinity of Hermosillo, the capitol of the state of Sonora, were also tested and analyzed. The results of these tests are presented in Table 3. The same general plan of procedure was followed in testing these samples as in the case of the first group of Jalisco wheats, *i. e.*, they were milled into straight flours on which the tests were made. These wheats were all of the white type and appeared much more pure and free from admixtures than were the other wheat samples examined. Samples Nos. 50, 51, and 55 were reported to have been grown under dry-farming conditions, and Nos. 53 and 54 under irrigation. However, the average quality of the wheats grown without irrigation did not appear to be superior to those grown under irrigation. In this they appear to show exceptions to the usual rule. The average percentage of crude protein and crude gluten in the flours milled from these wheats was found to be lower than in those from the Jalisco wheats, and the loaves of bread baked from them were decidedly small in volume. In general quality they rank with the poorest wheats grown in the United States.

Table 3.—*Composition of Sonora Wheats, and Composition and Baking Tests of Straight Flours Produced from Them in the Experimental Roller Mill.*

Sample Number.	Yield of Straight Flour.	Composition of Wheat.		Composition of Straight Flour.						Baking Tests.		
		Crude Protein.	Ash.	Moisture.	Crude Protein.	Ash.	Acidity.	Crude Gluten.		Loaf Volume.	Water Used.	Color Score.
								Wet.	Dry.			
	per ct.	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*c.c.*	*per ct.*	
50	64.4	10.45	1.93	9.35	8.85	.84	.090	24.9	8.73	1,410	60.3	85
51	68.0	9.09	1.83	9.51	7.85	.65	.112	22.1	7.42	1,300	57.6	88
53	71.3	10.08	1.80	9.05	8.91	.65	.....	28.9	8.94	1,640	61.2	94
54	71.0	10.80	1.80	8.48	10.01	.79	.....	29.4	8.49	1,400	59.1	88
55	70.0	12.04	1.69	8.78	11.25	.71	.....	36.6	11.59	1,510	60.9	82
Average	68.9	10.49	1.81	9.03	9.37	.73	.101	28.4	9.03	1,452	59.8	87

Composition and Quality of Commercial Flours.

The commercial flours collected in connection with this investigation were subjected to the same tests and analyses as were the flours produced here in the experimental mill. The results of these tests, together with the mill in which each sample was produced, are shown in Table 4. Mills A, B, and C were located in Guadalajara, and are briefly described above; mill D is the Atequiza mill, three samples being obtained from this source. The exact source of sample No. 33 is not known to the writer at this time except that it represents a brand which figures in the flour trade of Guadalajara.

Table 4.—*Composition and Baking Tests of Commercial Flours Produced in the Flour Mills of Guadalajara, Jalisco, Mexico.*

Sample Number.	Mill.	Composition of Flour.						Baking Tests.		
		Moisture.	Crude Protein.	Ash.	Acidity.	Crude Gluten.		Loaf Volume.	Water Used.	Color Score.
						Wet.	Dry.			
		per ct.	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*per ct.*	*c.c.*	*per ct.*	
5	C	11.34	9.57	.58	....	31.2	9.87	1,860	57.6	94
6	B	11.40	9.38	.58	....	27.6	10.02	Not enough to bake		
7	D	11.69	9.00	.56	....	27.0	8.32	1,510	54.7	95
8	A	11.57	9.28	.50	....	30.4	9.41	1,850	52.9	96
9	B	9.72	9.78	.62	.117	30.6	9.95	1,990	53.5	96
10	A	9.89	9.83	.46	.110	28.1	8.31	2,280	55.9	101
11	D	9.82	9.15	.59	.135	25.9	8.94	2,010	57.4	96
12	B	9.49	9.58	.60	.115	32.7	9.89	2,210	55.9	98
27	A	10.04	11.64	.48	.080	39.8	12.42	2,520	55.9	102
29	A	9.64	9.99	.50	.095	22.6	10.27	2,390	54.4	101
31	A	9.50	11.23	.64	.075	33.0	11.49	2,460	55.3	102
33	....	10.90	8.67	.64	.155	25.0	8.29	1,380	61.8	99
35	B	9.45	9.63	.68	.125	32.7	9.97	2,120	55.0	73
36	B	9.93	10.89	.58	.160	35.9	10.76	2,220	56.2	92
59	B	13.06	9.98	.60	.105	33.9	10.46	1,950	50.9	97
60	B	10.97	10.18	.57	.120	32.5	10.08	2,060	53.5	97
61	B	10.59	9.83	.59	.110	32.7	10.27	2,080	52.4	97
62	B	10.79	9.79	.61	.105	32.5	10.23	2,140	52.9	97
63	B	10.73	9.62	.61	.100	32.7	10.03	1,920	51.5	98
64	A	9.81	8.57	.49	.070	29.3	9.14	2,300	53.5	97
65	C	9.70	9.46	.54	.095	32.5	10.36	2,320	56.5	99
66	A	10.99	9.59	.47	.090	31.2	10.25	2,090	55.3	102
67	D	10.20	9.23	.59	.050	26.7	9.04	1,650	54.4	96
Average....		10.46	9.73	.57	.106	30.7	9.90	2,060	54.9	94.5

In general, these flours resemble very closely the straight flours produced from Jalisco wheats in our experimental mill, the tests of which are shown in Table 1. The percentage of ash is higher in the latter and the color score lower because, as above mentioned, they were imperfectly freed from soil particles. The other conclusions concerning the tests of the straight flours apply equally well in the case of these commercial flours. There are two quite notable exceptions however, these being Nos. 27 and 31, both of which contained over 11 percent of crude protein, and yielded loaves of 2,520 c.c. and 2,460 c.c. in volume, respectively, and scoring 102 in color. With these exceptions the flours are not such as would be regarded as satisfactory for bread-making in this country, at least not by bakers. They resemble in certain respects what is known to the flour trade as cracker or biscuit flour, although not so well milled and highly purified as most of the flours of the latter type produced in mills of the United States.

THE EFFECT OF SOIL MOISTURE, PLANT FOOD, AND AGE ON THE RATIO OF TOPS TO ROOTS IN PLANTS.

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The root growth of plants without doubt has a very important bearing on agriculture and yet but little work has been done on the subject in comparison with the great investigations that have been conducted regarding the parts of plants growing above ground. This is probably due to the many difficulties encountered in the study of roots.

1. LITERATURE.

A number of the earlier workers on physiology and agriculture made studies of root growth as affected by various factors.

Sachs[1] showed that the more concentrated the nutrient solution the shorter the roots, and Liebig said: " Plants search for food as if they had eyes."

Nobbe,[2] raising clover and maize in a soil which consisted throughout of the same basal material but with alternate layers saturated with nutrient solution, showed that the roots branch much more freely in soils which contain abundant food materials than in those which are poor in them.

Volkens[3] in 1887 described the great root growth of plants in arid regions. In the Egyptian desert he observed roots that were twenty times as long as the part above ground.

Fruwirth[4] and Kraus[5] have given some valuable data regarding the grouth of roots, especially at different periods in the life of the plants. The legumes were given particular attention.

Müller-Turgau[6] has done considerable work on the effect of nitrogen and of mixed salts on the growth of roots. The presence of nitrogen in a nutrient solution caused a much more vigorous growth of secondary roots. He found that a concentrated solution of mixed salts retarded root growth and that the best growth was obtained in weak solutions. Overfertilizing of the pots checked the growth of new roots.

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[1] Sachs, J. von, Handbuch der Experimental Physiologie der Pflanzen, p. 177, 1865.

[2] Nobbe, Versuchstationen, 4: 217, 1862, and 10: 94, 1868.

[3] Volkens, Die Flora der Ägyptisch-Arabischen Wüste, Berlin, 1887.

[4] Fruwirth, C., Fort. Geb. Agr. Phy., 18: 461–480, 1895.

[5] Kraus, C., Fort. Geb. Agr. Phy., 18: 113–166, 1895.

[6] Müller-Turgau, H., Jahresber. vers. sta. Wadensweil, 4: 48–52, and 1897–1898, pp. 79–82.

Tucker and von Seelhorst[7] using soil containing three different contents of moisture found that there were relatively more roots with low than with high soil moisture. They also found the roots to be relatively more in unfertilized than in fertilized soil.

Von Seelhorst[8] carried on rather elaborate tests with a uniform soil so arranged that he could determine the number of roots in each 25 cm. section to a depth of 150 cm. From tests with rye, spring and winter wheat, barley, peas, beans and field beets, he concluded that plants, when liberally fertilized, not only have a larger root system but those roots descend deeper into the soil, and are thus able to better withstand drought.

Rotmistrov[9] devised some ingenious methods of studying roots and has reported considerable work on the effect of various factors on root growth.

McCool[10] and many other workers have demonstrated that various salts in solution affect the ratio of tops to roots.

There has been considerable work done in this country on the distribution of the roots of plants grown in the field. Hays[11] working in Minnesota made a fairly thorough study of the distribution of corn roots, especially as related to tillage operations. King[12] in Wisconsin studied the root distribution of most of the common field crops. Ten Eyck,[13] who had worked with King in Wisconsin, continued similar studies in North Dakota and Kansas, and Shepperd[14] continued the work of Ten Eyck in North Dakota. Experiments along this line have also been conducted at the New York, Pennsylvania, Colorado, Utah and other stations.

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[7] Tucker, G. M., and Seelhorst, C. von, Jour. für Landw., **46**: 52–63, 1898.

[8] Seelhorst, C. von, Jour. für Landw., 50: 91–104, 1902.

[9] Rotmistrov, V. G., M. of L. and A., Dept. of Agr. Publication, pp. 57, Figs. 22, 1909. South Russia Printing Co., Odessa. (See Distribution of Roots in Annual Cultivated Plants, Zhur. Opuitn. Agron. (Russ. Jour. Expt. Agron.), 8: 667–705 (1907) and 9: 1–24, Figs. 14, 1908; also in Rept. of Odessa Expt. Farm (Imp. Agrl. Soc. of South Russia), **13**: 60–143, Figs. 14 (1907) 1909.

[10] McCool, M. M., Cornell Agr. Exp. Sta. Memoir No. 2, pp. 121–216, 1913.

[11] Hays, W. M., Minn. Sta. Bul. No. 5, 1889.

[12] King, F. H., Wis. Sta. Ann. Rept., 9: 112–120, 1892, and 10: 160–163, 1893.

[13] Ten Eyck, A. M., North Dakota Sta. Bul. No. 36: 333–362, 1899, and 43: 533–560, 1900; Kansas Sta. Bul. No. 27: 199–252, 1904.

[14] Shepperd, J. H., North Dakota Sta. Bul. No. **64**: 623–636, 1905.

There is, in spite of all this work a great need for results obtained under field conditions on the effect of various soil treatments on the growth of roots. It is a difficult problem, but it should be undertaken by someone.

2. Wheat Plants in Soil Extracts.

In order to determine the effect of the concentration of the nutrient medium on root growth a number of soils were extracted as follows: The soil and distilled water were mixed in equal weights and stirred thoroughly for three minutes, then allowed to stand thirty minutes. The mass was then placed on a paper filter. The filtrate is the concentrated extract mentioned below. This was diluted one part to four of distilled water to give the dilute extract. Wheat seedlings having previously been germinated were held in slit corks placed in bottles containing the soil extracts. The extract in which the plants were grown was discarded and replaced by fresh each week. The plants were allowed to grow three weeks, when they were harvested and determinations made of the length, green weight and dry weight of the tops and roots. The results are shown in Table 1.

Table 1.—*Ratio of Tops to Roots of Wheat Seedlings Grown 3 Weeks in Soil Extracts of Different Concentration.*

Soil.	Extract.	Green Weight.			Dry Matter.			Average Length.		
		Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.
		grams	*grams*		*grams*	*grams*		*inches*	*inches*	
A	Conc.......	2.34	2.59	.90:1	.4742	.3261	1.46:1	5.1	4.8	1.06:1
A	Dilute.....	1.42	2.45	.58:1	.2533	.4297	.59:1	4.3	8.7	.49:1
B	Conc.......	2.56	2.86	.90:1	.5142	.2980	1.72:1	6.0	8.2	.73:1
B	Dilute.....	1.51	2.86	.53:1	.2866	.3125	.92:1	4.9	9.5	.52:1
C	Conc.......	1.48	2.63	.56:1	.3019	.3354	.90:1	4.7	8.2	.57:1
C	Dilute.....	1.18	2.01	.59:1	.2356	.2810	.84:1	4.2	6.8	.62:1

Average for all concentrated and all dilute extracts.

	Conc.......	2.13	2.69	.79	.4301	.3198	1.38	5.3	7.1	.75:1
	Dilute.....	1.37	2.44	.56	.2585	.3411	.76	4.5	8.3	.54:1

From the table it will be seen that the ratio of tops to roots was always greater with plants grown in concentrated than in dilute soil extracts. This rule held for green weight, dry weight and length. The concentrated extracts always produced more tops than the dilute, but the root growth was sometimes greater in the dilute.

3. CORN IN SAND WITH VARYING MOISTURE CONTENT.

Corn was raised in coarse quartz sand in glass tumblers for 17 days with moisture varying from 11 to 38 percent of the dry weight of the sand. The one was very dry and the other contained free water. There were five plants in each tumbler. The results are given in Table 2.

TABLE 2.—*Green Weight and Length of Corn Tops and Roots Grown with Different Amounts of Water.*

Percent Water.	No. of Plants.	Green Weight in Grams.			Length in Inches.		
		Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio of Tops to Roots.
38	5	3.63	4.05	.90:1	5.4	3.7	1.46:1
30	5	3.54	4.21	.84:1	6.8	5.8	1.17:1
20	5	3.36	5.18	.65:1	6.0	11.3	.53:1
15	5	2.35	4.90	.48:1	4.7	10.9	.43:1
11	5	1.56	4.30	.36:1	3.1	9.5	.33:1

In the wettest sand the roots weighed only slightly more than the tops while in the driest they were nearly three times as heavy. The length of tops in proportion to roots also gradually decreased as the water decreased. The longest and heaviest roots were produced with a medium amount of water, while the greatest weight of tops was produced with 38 percent moisture and the highest tops with 30 percent.

4. WHEAT IN SAND.

Wheat was raised for 19 days under conditions already described for corn. Ten seeds were planted in each tumbler but only part of them grew so the actual weights cannot be well compared. The results are given in Table 3.

TABLE 3.—*Green Weight and Length of Wheat Tops and Roots Grown with Different Amounts of Water.*

Percent Water.	No. of Plants.	Green Weight in Grams.			Length in Inches.		
		Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio of Tops to Roots.
38	5	.46	.52	.88:1	3.9	2.2	1.77:1
30	10	1.09	1.67	.65:1	6.4	8.2	.78:1
20	8	.57	.88	.65:1	4.7	9.6	.49:1
15	6	.35	.60	.58:1	3.7	9.9	.37:1
11	8	.47	.55	.86:1	3.7	9.9	.37:1

While the results on the weight of tops and roots of wheat were not as regular as those with corn, still the same rule seems to hold.

There was a gradual decrease in the relative length of tops as the soil moisture was lowered.

5. PEAS IN SAND.

Peas were also grown under the conditions described for corn and wheat. The sand containing 38 percent water was too wet for the germination of peas although the corn and wheat germinated in it. The results are given in Table 4.

TABLE 4.—*Green Weight and Length of Pea Tops and Roots Grown with Different Amounts of Water.*

Percent Water.	No. of Plants.	Green Weight in Grams.			Length in Inches.		
		Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.
38	No Germination						
30	6	3.02	3.73	.80:1	5.85	7.3	.80:1
20	5	1.90	2.75	.69:1	4.70	7.3	.64:1
15	6	1.97	3.65	.54:1	3.33	6.1	.55:1
11	6	1.85	3.27	.57:1	2.55	6.6	.39:1

The table for peas shows the same general results as those for corn and wheat.

6. CORN IN GLASS TUBES.

It was thought desirable to have plants growing in such a way that the growth of roots, as well as tops, could be observed from day to day. Accordingly glass tubes ⅞ of an inch in diameter were filled with soil which was well compacted. Two kernels of corn were planted in each tube and the tubes inclined at an angle of 30° from the vertical. As a result the roots kept near the glass in their attempt to grow straight down and they could be easily observed. The water for the plants was obtained by keeping the lower ends of the tubes immersed in water. The depth of immersion was varied so that the water was all the way from 6 to 60 inches below the surface of the soil in different tubes. Where the free water was 6 inches below the surface the soil was kept practically saturated all the time, while where it was 60 inches below the surface there was barely enough water raised by capillarity to supply the needs of the plants. Thus there was every gradation from a real wet to a comparatively dry soil.

The plants were allowed to grow for 75 days, measurements being made of the roots and tops a number of times during this period. The results are shown in Table 5. Green weights were made of the roots and tops when the plants were harvested.

TABLE 5.—*Length of Tops and Roots of Corn at Different Periods when Grown in Glass Tubes with Varying Depths of Water.*

Depth of Free Water.	Length in 5 Days. Inches.			Length in 18 Days. Inches.			Length in 30 Days. Inches.			Length in 75 Days. Inches.		
	Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.
6 in.	6.7	9.0	.74:1	10.0	13	.77:1	11	13	.85:1	12	13	.92:1
12 in.	8.6	13.0	.66:1	17.5	18	.97:1	18	18	1.00:1	19	19	1.00:1
24 in.	7.0	18.0	.39:1	19.0	25	.76:1	21	28	.75:1	22	29	.76:1
30 in.	6.8	19.0	.36:1	13.5	28	.48:1	17	30	.57:1	17	37	.46:1
36 in.	5.0	11.0	.45:1	15.5	34	.46:1	20	43	.47:1	24	46	.52:1
42 in.	5.5	16.0	34.:1	9.0	31	.29:1	15	42	.36:1	20	42	.48:1
60 in.	4.0	18.0	22.:1	6.0	38	.16:1	10	70	.14:1	17	70	.24:1

The table shows that the ratio of tops to roots decreases with a fair degree of regularity as the free water was lowered. Whre the water was five feet below the surface and the soil rather dry the roots were a number of times as long as the tops but on the wetter soils the tops and roots were about the same length. In the drier soils the ratio of tops to roots usually decreased with the age of the plants, while with the soils containing water near the surface the opposite was true. It is probable that the latter condition was brought about by the roots striking free water and ceasing to go any deeper, due to the lack of oxygen in the water. The tops, however, continued to grow. The final weights are shown in Table 6.

TABLE 6.—*Weight of Corn Tops and Roots from Tubes after Growing 75 Days.*

Depth of Free Water.	Green Weight in Grams.		
	Tops.	Roots.	Ratio Tops to Roots.
6 in.	3.2	7.2	.44:1
12 in.	6.6	12.0	.55:1
24 in.	9.0	18.3	.50:1
30 in.	Tube Broken.		
36 in.	8.9	22.8	.39:1
42 in.	8.7	19.5	.45:1
60 in.	6.2	25.5	.24:1

The results for the weights are similar to those for lengths except that they are somewhat irregular. In general there is a decrease in the relative weight of tops as the water table lowers.

7. ROOTS OF THE SAME CORN PLANT WITH DIFFERENT AMOUNTS OF SOIL MOISTURE.

In order to determine how various roots of the same plant would be affected by the amount of water in the soil, a kernel of corn, after having been germinated, had all but two of its rootlets removed. It was then so placed that one of these roots could grow in sand that was only slightly moist, while the other grew in sand that was nearly saturated with water.

The experiment was begun on April 7. On June 25 the plant was removed and measurements made. The longest root in the wet sand was 6 inches long and it had quite a number of short stubby branches. In the drier soil the root was 36 inches long and was composed of 3 main branches. The corn top was at this time 10 inches high.

8. Corn During Germination Stage.

Tests were made to determine the effect of the soil moisture on the different parts of the seedling during germination. Sand was placed in shallow pans and made up to different percentages of moisture. Corn was then placed between filter papers on the sand and allowed to germinate. Measurements were made 5 and 7 days after the seeds were set to germinate. Table 7 shows the results obtained. The table is the average of 50 seeds.

Table 7.—*Length of Corn Tops and Roots During the Germination Stage as Affected by Soil Moisture.*

Percent Soil Water.	Measurements 5 Days After Planting.			Measurements 7 Days After Planting.		
	Length Tops, Cm.	Length Roots, Cm.	Ratio Tops to Roots.	Length Tops, Cm.	Length Roots, Cm.	Ratio Tops to Roots.
5	....	1.0	....	....	1.0	....
10	....	2.0	....	....	3.0	....
15	....	2.0	....	.4	5.0	.08:1
20	....	3.0	....	.5	5.0	.10:1
25	....	3.0	....	.5	7.0	.07:1
30	.1	3.0	.03:1	.7	7.0	.10:1
35	.5	5.0	.10:1	1.5	9.0	.17:1
40	2.0	8.0	.25:1	6.0	15.0	.40:1
45	.8	2.0	.40:1	2.0	4.0	.50:1
50	.5	1.0	.50:1	.7	2.0	.35:1

The table shows that the corn root makes a distinct growth before the top begins and the ratio of tops to roots increases with the soil moisture. Except in the case of the very highest water content the relative length of tops was greater during the later stage of germination than earlier.

9. Wheat During Germination Stage.

Wheat was placed under conditions similar to those just described for corn. The amounts of water and the days of observation, however, were slightly different. These results are given in Table 8.

TABLE 8.—*Length of Wheat Tops and Roots During the Germination Stage as Affected by Soil Moisture.*

Percent Soil Moisture.	Measurements 4 Days After Planting.			Measurements 7 Days After Planting.		
	Length Tops. Cm.	Length Roots, Cm.	Ratio Tops to Roots.	Length Tops, Cm.	Length Roots, Cm.	Ratio Tops to Roots.
5	.1	.10	1.00:1	.3	.35	.86:1
9.2	.1	.13	.77:1	.3	.50	.60:1
13.6	.2	.80	.25:1	.4	.80	.50:1
17.9	.2	.30	.67:1	.8	1.80	.45:1
22.1	.2	.30	.67:1	2.0	2.30	.87:1
26.4	1.1	1.90	.58:1	2.5	2.90	.86:1
30.7	1.8	2.20	.82:1	5.0	4.00	1.25:1
35.0	1.8	2.20	.82:1	4.0	3.50	1.14:1
39.3	1.5	.90	1.67:1	2.7	1.90	1.42:1
43.6	.2	.15	1.33:1	.2	.15	1.33:1

The results with wheat are, in general, the same as those with corn but they are not so regular. This in part is due to the difficulty of getting accurate measurements of the very young wheat seedlings.

10. WHEAT HARVESTED AT DIFFERENT STAGES.

Wheat plants were raised in 4-gallon earthen jars containing Dunkirk clay loam. There were three different fertilizer treatments, each with two different amounts of moisture. Each pot contained twelve wheat plants. The plants in some pots were harvested when the wheat was in the boot stage, in others when in bloom and still others when the plants were mature. Each figure represents an average of two duplicate pots. The complete fertilizer was applied at the rate of 300 pounds $NaNO_3$, 100 pounds KCl and 300 pounds acid phosphate per acre. The high nitrogen fertilizer was the same except that

TABLE 9.—*Dry Weight of Wheat Tops and Roots at Various Stages when Grown in Soil with Different Amounts of Fertilizer and Moisture.*

Fertilizer.	Percent Soil Moisture.	Dry Matter in Grams.								
		Boot Stage.			Bloom Stage.			Maturity.		
		Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.	Tops.	Roots.	Ratio Tops to Roots.
None.......	30	35.31	15.80	2.2:1	50.54	10.73	4.7:1	74.95	9.31	8.1:1
None.......	15	15.21	10.02	1.5:1	19.38	8.82	2.2:1	29.28	9.59	3.1:1
Complete...	30	45.48	22.87	2.0:1	76.24	14.36	5.3:1	102.02	11.71	8.7:1
Complete...	15	27.79	20.76	1.3:1	39.96	12.46	3.2:1	52.32	13.19	4.0:1
Complete with High N........	30	39.69	14.13	2.8:1	65.97	12.65	5.2:1	112.12	11.45	9.8:1
	15	26.50	18.29	1.4:1	39.47	11.40	3.5:1	37.78	13.19	2.9:1

1000 pounds of $NaNO_3$ to the acre were used instead of 300 pounds. The fertilizer was thoroughly mixed into the surface two inches of soil before the seeds were planted. Table 9 shows the results obtained.

This table brings out clearly that the proportion of roots is greater when the plant is young than after it gets older. This held for practically every moisture and fertilizer treatment. The roots were also proportionately more with the low than with high moisture, and in the unfertilized than in the fertilized soil.

11. Wheat Grown to Maturity with Varying Soil Moisture at Different Stages.

Experiments were conducted in 4-gallon earthen jars under conditions and with soil already described, and the wheat allowed to mature. The life of the plant was divided into 3 stages: the first being from planting till there were five leaves on the plants, the second from the five-leaf stage to the boot stage, and the third from the boot stage to maturity. In one set of pots the soil was kept at 30 percent of water all during the growth of the plants. In another set the soil was kept at 15 percent during all three stages. In the other sets the soil moisture was varied during the different stages, as shown in Table 10. There were six pots in each moisture treatment, two for each of the three fertilizer treatments already described in connection with Table 9. The roots were washed out with a fine spray nozzle, considerable time being taken not to lose the roots.

Table 10.—*Dry Weight of Wheat Tops and Roots Grown to Maturity with Different Soil Moisture at Various Stages.*

Percent Soil Moisture.			No. of Pots.	Dry Weight in Grams.		Ratio of Tops to Roots.
1st Stage.	2d Stage.	3d Stage.		Tops Straw + Grain.	Roots.	
30	30	30	6	44.89	5.41	8.3:1
30	30	15	6	40.53	6.76	6.0:1
30	15	15	6	34.64	6.06	5.7:1
15	15	15	6	19.89	5.99	3.3:1
15	15	30	6	27.91	5.73	4.9:1
15	30	15	6	33.19	8.58	3.9:1

The table brings out some interesting relations between the tops and roots as affected by the time the plants received high or low water. There were proportionately more tops with high than with low water and if the water was high during two stages the proportion of tops was greater than where high during but one stage. High water during the first decreased the proportion of roots more than during any other single stage.

12. Wheat Grown to Maturity with Different Fertilizers.

As explained in the previous section the wheat grown with various amounts of moisture was divided into three fertilizer treatments When the results shown in Table 10 are arranged according to the fertilizer received Table 11 is obtained. Each figure is the average of 12 pots with 6 different moisture treatments.

Table 11.—*Dry Weight of Wheat Tops and Roots Produced with Different Fertilizers.*

Fertilizer.	No. of Pots.	Dry Weight in Grams.		Ratio Tops to Roots.
		Tops Straw + Grain.	Roots.	
None	12	26.33	5.91	4.5:1
Complete	12	37.90	6.53	5.8:1
Complete with high N	12	37.96	6.83	5.6:1

This brings out clearly the point already mentioned in connection with Table 9, that the tops are proportionately higher in the soil receiving fertilizer than when no fertilizer was added. The additional nitrogen in the fertilizer did not increase this ratio.

13. Summary.

1. A report is given of some of the important literature on the factors affecting the ratio of the tops of plants to roots.
2. It was shown that with wheat seedlings growing in soil extracts the green weight, dry weight and length of roots was proportionately greater in the dilute than in the concentrated soil extract.
3. Corn, wheat and peas growing a number of weeks in sand containing different amounts of moisture showed a proportionately greater root growth in the drier sand.
4. Corn grown in glass tubes 75 days showed a relatively greater root growth where the level of free water was a considerable distance below the surface.
5. Different roots of the same corn plant grown in very wet and in moist sand showed a greater root growth with the lower amount of water.
6. Tests with corn and wheat showed that the ratio of tops to roots was affected by soil moisture even during the germination stage.
7. Wheat harvested at different stages showed relatively more roots during early stages of plant growth than later.
8. Wheat grown to maturity showed a greater relative root growth with low than with high soil moisture, and the moisture during the early stages of growth had the greatest influence on that ratio.

9. Fertilizers added to the soil reduced the relative root growth of wheat.

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THE NAME OF THE SOY BEAN: A CHAPTER IN ITS BOTANICAL HISTORY.

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In connection with a study of the oriental species of *Phaseolus* cultivated in India, Japan, China and elsewhere, most of which species have been under test for a number of years at Arlington Farm, Virginia, it became necessary to clear up the botanical identity of each. The botanical literature showed that there was a diversity of opinion among botanists regarding the identity of certain species described by Linnæus, especially *Phaseolus radiatus, P. max,* and *P. mungo*. The most far reaching studies on this problem were those made by Prain.[1] Prain's conclusions were based on his wide knowledge of the Indian species, but only a limited acquaintance with those of Japan and China. Unfortunately in his studies he did not have access to any of the old material on which the Linnæan names are based. His conclusions at that time were that the name *P. radiatus* belongs to the species cultivated under the name Mung; *P. mungo* to the one called Tikari in twining varieties, and Urd or Urid in bushy sorts; and that *P. max* is a composite species based partly on a Mexican plant and partly on the *cadelium* of Rumphius which latter is the soy bean.

In connection with the writer's studies of *Phaseolus,* it became evident that there still existed discrepancies in the literature which did not seem reconcilable with any conclusions yet published.

Perhaps the most interesting of these problems is that which concerns the identity of *Phaseolus max* Linn. Linnæus' original description of this plant is as follows:

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[1] Journal of the Asiatic Society of Bengal, Vol. II, pp. 422–423, 1897.

Phaseolus Max.—

> "Phaseolus caule erecto anguloso hispido, leguminibus pendulis hirtis. Hort. Cliff. 499. Roy lugdb. 367. Fl. zeyl. 280.
>
> "*Phaseolus orthocaulis,* Mungo persarum. Hern. mex. 887. Habitat in India."

The first reference in this description is the Hortus Cliffortianus in which work Linnæus described in 1737 a plant as follows:

> "2. Phaseolus caule recto anguloso hispido.
>
> Phaseolus erectus, caule & folio rigidis, flore pallide luteo, siliqua crassa & ampla. *Boerh. ind.* 152.
>
> Phaseolus ortocaulis, Mungo persarum, turcarum Masc, hispanorum Max. *Hern. mex.* 887. *Boerh. lugdb.* 2. p. 28.
>
> *Crescit in* Virginia, *unde e seminibus delatis prodiit.*"

According to the description, the Cliffortian plant was grown from seed said to have come from Virginia.

The first reference cited in "Roy. lugdb. 367" as well as in "Fl. Zeyl. 280" is also to this Cliffortian plant. The Mexican plant of Hernandez is not definitely known, but Savi supposed it to be identical with the plant which in 1882 he called *Phaseolus hernandezii.* Manifestly the statement "Habitat in India" could hardly refer either to the Virginian or to the Mexican plant. Following the "Fl. Zeyl. 280" reference further, one is led into a maze of citations that concern East Indian plants, some of which undoubtedly refer to the Mung. If one restricts the line of search to Indian plants the clue apparently leads to a plant collected by Hermann in Ceylon and at that time called by the natives, Bumum or Buncæ.

At this stage of the investigation the assistance of Sir David Prain, director of the Royal Botanic Gardens, Kew, was secured, as his wide knowledge and previous studies of the East Indian species of *Phaseolus* rendered him preeminently equipped to clear up this problem as well as several related ones. The very interesting outcome of his studies can not be better stated than in his own words.

"*Phaseolus max* Linn.

"Till I took up the question on your behalf I thought with you that this is as puzzling a case of confusion as may be found in Linnæus. On studying the matter, however, though the confusion is very evident, the muddle proves to be a fairly simple one. It is truly the unexpected that happens in this particular case and of the three debateable 'species' *P. max* comes out as the only one in respect of which we are able to say with any certainty (*a*) what the plant named *P. max* is and (*b*) what the plant which Linnæus intended to name *P. max* may be. It is better to separate these two parts of the story.

"What *P. max* is we know with certainty because in the first place there is in the Linnæan herbarium a specimen which, with his own hand Linnæus has written up as *Max*. His register of specimens shows that Linnæus had this one in his herbarium in 1753 and this we know must be an accurate statement because the specimen is one which came to Linnæus from Hort. Cliffort. and has upon it still, as all the Cliffortian specimens in Herb. Linn. have, the upper half of the peculiar Herb. Cliff. label.

"Next the specimen fits exactly the brief description 'caule erecto anguloso hispido leguminibus pendulis hirtis,' which Linnæus gives of *P. max*.

"It is very fortunate that Linnæus's specimen of *P. max* came from Hort. Cliffort. because it so chances that this is one of the Cliffortian plants of which there is no example in the British Museum. The record that the plant was grown in Hort. Cliffort. from seed secured in Virginia is one as to which I must leave you to decide upon the accuracy of. All that I know is that whether the plant was raised from seed secured in Virginia or not Linnæus was perfectly well aware that the species in question is a native of the old world. The reverse of the Cliffort. sheet bears the legend, in ink much older than that used by Linnæus to write the word *Max*, 'Ononis asiatica frutescens (or pubescens) floribus luteis amplis' (the third word is not very clearly decipherable). Thus much then for the specimen which testifies to the identity of the plant quoted from Hort. Cliff. 499 with that written up as *P. max*.

"Turning to the Fl. Zeyl. references which, as you justly remark, are clearly all traceable to Hermann's 'Bumum' and 'Buncæ,' we do not find the matter really very difficult. It is not unnatural to suppose that since both Mung and Urid occur in Ceylon—Bumum may have been one of them—Buncæ the other. Now since Trimen[1] uses the name 'Bume' which he finds associated with either Mung or Urid, we may with some safety conclude that this name in Ceylon indicates now what it indicated in Hermann's day. But Trimen's use of *P. max* as the proper scientific name for 'Bume' though seemingly justified on bibliographical grounds will not bear closer examination because the plant upon which Linnæus wrote the name *P. max* is neither Mung nor Urid.

"As regards 'Buncæ' there is at least a chance that Hermann's plant was also the Linnæan one. This I say because in the British Museum collection, among the original specimens written upon by Loureiro there is one, which he has written up as 'Bancus,' which is at the same time identical with the type of *P. max* Linn.

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[1] Trimen, Handbook of the Flora of Ceylon, Part II, p. 72, 1894.

"When we turn to Hermann's herbarium we find the actual specimen Linnæus had in view. That specimen, as Wight and Arnott[1] say, has no flowers. They might have added, with rather more point, that now it has no fruits. But they have omitted to give us the important information that this specimen, to which Hermann has *not* added the names 'Bumum' or 'Buncæ,' but to which he *has* added the number '280' is one of those of which a contemporary drawing exists in the volume accompanying the specimens. That drawing is a beautiful and accurate drawing, *with fruits,* of the very species which Linnæus in his own herbarium wrote up as *P. max*. The plant of the Flora Zeylanica, of the Hortus Cliffortianus, of the Species Plantarum Ed. 1, and the plant represented in Herb. Linn. by the specimen written up as *P. max* are all one thing.

"What then, you will ask, is this *P. max* Linn., as represented by the two specimens of Hermann and of Clifford? *P. max* Linn. is the plant which Rumphius figured and described as Cadelium, subsequently referred by Linnæus himself to *P. max*. In short, *P. max* Linn. Sp. Pl. 725 is the same thing as *Dolichos Soja* Linn. Sp. Pl. 727. The only difference between them is that *Dolichos Soja* though written about by Linnæus in 1753 was not seen by him until he grew specimens of it in Hort. Upsal., which specimens he recorded the existence of, for the first time, in 1767.

"What Linnæus meant by *P. max,* as contrasted with what he named *P. max,* we reach if we follow the clue afforded by his citation 'Phaseolus orthocaulis, Mungo persarum, Hern. Mex. 887.' When we turn to the passage indicated we find (1) that the actual phrase is 'Mungo, sive Phaseolus orthocaulis' so that the citation is incorrect; (2) that the article begins: 'Mungo, apud Indos orientales a Persio, ac etiam a Turcio dicitus Masc quod ab Hispanis diceretur Max.,' so that the expression 'Mungo persarum' reverses what is actually said; (3) that the names 'Mungo' 'Masc' and 'Max' are not employed by Hernandez at all because they occur in the separate treatise termed 'Annotationes et Additiones' written by Fabio Colonna. The article on 'Mungo' is one of the 'Additiones' not a mere 'Annotatio' so that it is attributable to Colonna alone.

"Clearly then Linnæus got his expression 'Mungo persarum' elsewhere and clearly the place whence he took it was Boerhaave's Ind. Alt. Lugds. Bat. II. p. 28 where we find recorded: '16 Phaseolus; octocaulis; Mungo Persarum; Turcorum Masc; Hispanorum Max. *Fab. Col. Annot. et Addit. in Nard. Ant. Recch.* p. 887.' Here we find a misreading of the name 'orthocaulis,' which Linnæus avoided, with a correct citation of authority which Linnæus did not choose to follow. The interesting feature of this citation is that it supplies us with the source of the specific epithet *Max* and of the erroneous expression 'Mungo persarum' wrongly attributed to Hernandez.

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[1] Wight and Arnott, Prodomus Florae Peninsulae Indiae Orientalis, 1: 245, 1834

"The punctuation in Colonna's passage is certainly singularly inept but the concords are unimpeachable and afford as little excuse for the misleading paraphrase of Colonna's statement as there is for the misreading of the name 'orthocaulis.'

"Colonna's article deserves more careful consideration than it has hitherto been given. After supplying a fair description of the plant intended, and a rough figure which suits best the plant that is *P. max* Roxburgh,[1] not at all of Linnæus, Colonna describes the germination of the seeds in a fashion that leads one to believe him to be describing what he has seen with his own eyes.

"But the principal points to be noted are that Colonna does not say the plant is a Mexican one; he does not quote for it any Mexican name. On the contrary he uses for it two Asiatic names with the Spanish (or Portugese) variant of one of them and still further shows his acquaintance with the fact that it is an old world species by giving a Latin version of what Garcia del Huerto had to say about the same Indian plant. We see from this version that Colonna went to Garcia's original text and did not quote from Clusius's Latin translation of Garcia issued in 1567.

"There is no reason why by 1651 Mung should not have been introduced as a food for horses into Mexico. But there is also no proof that the article was intended by Colonna as more than a suggestion to the Spaniards that a horse-food so useful as this was known to be in India, might with advantage be introduced into Mexico.

"But, I repeat, there is no claim that the plant roughly figured by Colonna was, even as an introduced species, already in Mexico and the only justification that Savi had for daring to identify with Colonna's rough figure of Mung an innocent American species was the circumstance that Colonna gave an account of this Asiatic one as an addition to an article in a book about Mexico.

"There is only one other Linnean reference to deal with: 'Fructus nigrum coriandro similis, Bauh. Pinax 413 (1623).' The origin of this, is, like the origin of Colonna's, to be found in Garcia's account of 'Mungo' as translated into Latin by Clusius. In the first edition of Clusius's version we find on p. 238: 'Est vero mungo semen viride quod per maturitatem sit nigrum, Coriandri sicci magnitudine. Pabulum est equorum, interdum tamen etiam ab hominibus editur. Guzarate et Decan incolae in febribus utuntur.'

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[1] *Phaseolus max,* as described by Roxburgh, is a black-seeded variety of mung. C. V. P.

"Not only the idea but the words in which it is expressed are taken by Bauhin direct from Clusius's Garcia and the fact that he was quite unaware of the nature of the plant is proved by his alteration of 'semen,' which is sense, to 'fructus,' which is not.

"After a paragraph devoted to its utilities the Clusian version of Garcia goes on: 'Nasci etiam ferunt in Palaestina hoc Mungo. Ejus meminit Avicenna, lib. 2, cap. 488 vocatque Messe, Bellunensis eius interpres Mens (Mex autem debere dici ab eruditis medicis Arabicis edoctus sum), item alio loco, lib. 1, Fe. 3, cap. 7 ubi prohibit aviculas cum Mex edi. . . .'

"Regarding the name 'Messe' as given by Garcia, Clusius has a marginal note 'Meisce habent nostra exemplaria' (of Avicenna). So has the only copy of Avicenna at Kew for it reads (lib. 2, tractatus II., cap. 488) 'Meisce quid est? Est proximus substantiem fabarum,' a statement that does not give much information, but that is not incompatible with 'Meisce' of Avicenna and *P. max,* as *intended* by Linnæus, being the same thing.

"I have not seen any Mung or Krishna Mung from Palestine. But there are characteristic specimens of Krishna Mung from West Persia and it is of interest to see that Boissier who named them has written them up as *Phaesolus Hernandezii.* To this extent that name of Boissier is right; this *is* the plant figured by Colonna in the Additiones to Hernandez. But, apart from questions of priority, the name is not permissible really, because the American plant, specimens of which were issued by Savi as *P. Hernandezii,* is a different thing.

"In 1897 I pointed out that the Turki name for Krishna Mung was *Mash,* though in Northern India the name 'Mash' or 'Mash-Kulai' is not used for Mung but is employed in contrast to the name 'Mung' for the Urid crop.

"You will have noticed, however, that in 1908 Sir G. Watt, Commercial Products of India, p. 881, speaking of western India, the area to which Garcia's information as regards Mung was confined, says: 'It would appear that either the wrong scientific names have been used in the official publications of Bombay (and in Mollison's Text-Book Ind. Agric.) for this and the next pulse or that the names

"Mag," "Mung" and "Urid" have the opposite signification in Bombay to those prevalent in the rest of India.' When one considers the carefulness of authorities like Mollison it is on the whole more probable that the second explanation is the correct one.

"This phenomenon of the transference of names from one crop to another is not at all infrequent. Linguistically the Greek *καννaβις* the English 'hemp' and the Sanskrit 'cana' are identical. But while the Greek and the English words apply to the same plant, the Sanskrit word was transferred to the 'can' or 'canai'—the sunn hemp (*Crotalaria juncea*). The only thing in common between hemp and sunn is that both are fiber plants.

"Another case of the kind is the word 'Matar' which in Bengal always means *Pisum arvense* though it has got to be employed by English denizens as their word for *Pisum sativum* and in that signification has got carried all over British India. But the word 'Matar' except in the latter sense is not used at all in Upper India where the name for *Pisum arvense* is Kalai. However when we get over to Gujarat and Karachi we find 'Matar' again in common use but always as the name for *Lathyrus sativus!*

"Yet another instance: The Persian 'Sarshaf,' the Hindi 'sarso' and the Bengali 'Sarisha' are clearly linguistically the same word, yet 'Sarshaf' always means *Brassica nigra,* while 'Sarso' is the Sarson crop, a form of *B. campestris* and *'Sarisha'* is always the Tori crop, a form of *B. napus.* I could multiply examples of this process almost indefinitely, but the cases I have given you will suffice, I think, to support the conclusion to which I have now come: that Masc, Meisce, Mex, Max, Mash is a Turki or Persian name, restricted in Persia and Turkestan to the plant which is the Krishna Mung of India; that the Mahomedan invaders of India carried the word with them into the plains of Northern India but happened to apply it to the Urid crop, so that in time it has come to signify 'Urid' in contradistinction to 'Mung'; that on the other hand the Persian traders who took the word with them as part of their language to Western India chanced on the contrary to treat it as a synonym of the Indian 'Mung.'

In this latter sense, as a mere synonym of 'Mung,' Linnæus picked up the name from Boerhaave, just as Boerhaave had picked it up from F. Colonna and as Colonna had picked it up from Garcia.

"When Roxburgh was trying to account for the two Indian crops, 'Mung' and 'Urid,' he only did what was natural in trying to limit the name *P. mungo* L. to the Mung crop. Having done this it was only natural that the name *P. radiatus* should have been supposed by him to mean the Urid crop.

"Finding, as I did, that the Dillenian Hort. Eltham. plant referred by Linnæus to *P. radiatus* must be Mung rather than Urid, and seeing at the same time that the description of *P. mungo* applied better to Urid than to Mung, it was only natural for me to reverse the names.

"Now, however, I feel that both Roxburgh and myself were wrong in allowing ourselves to be influenced at all by the fact that there are two Indian crops. It was natural that we should; yet the fact remains that Linnæus used the name *P. radiatus* for a Chinese, not an Indian plant and that his type, though clearly a form of Mung, is not absolutely identical with any Indian form of the Mung crop.

"As regards *P. mungo* L. the fact remains that, whatever may have been the origin of the plant he describes, no specimen appears ever to have been added by Linnæus to his herbarium and all that we are justified, by the evidence available, in assuming is that Linnæus, in 1767, as already in 1753 deemed *Mungo* the precise equivalent of *Max*. If this be so, it may very fairly be asked why, in 1753, did Linnæus use *Max* in preference to *Mungo* and why in 1767 did he drop *Max* and use *Mungo* instead?

"The answer in both cases seems to me self evident. Of the two synonyms *Mungo* and *Max*, clearly *Max* was the oldest because *Mungo* occurs for the first time in Garcia del Huerto while *Max* goes back to Avicenna. Linnæus chose *Max* because of its greater age.

"In the other case Linnæus in all good faith supposed that 'Buncæ' of Hermann and the plant he saw in Clifford's Garden were the same thing as Mungo and Max, at the time he wrote the Flora Zeylanica. He had no suspicion that the plant he had described was different from the plant whose name he had adopted when he published the first edition of the Species Plantarum in 1753. He was still unconscious of the extraordinary blunder he had committed when he published the second edition in 1763. But some time after he had published the second edition of the Species Plantarum he obtained from some one seeds of the plant he had described in 1753 as *Dolichos Soja*. He raised plants from these seeds at Upsala and put specimens into his herbarium some time before 1767 when he for the first time recorded its existence in his collection.

"Linnæus was at last in a position to se that the plant he had described as *Phaseolus max* was the same as the one he had named *Dolichos Soja* and that the Mung crop (*Mungo* or *Max*) was still without a name. It may be that in putting matters right Linnæus felt that to continue for the 'Mungo' or 'Max' crop the name *Max* might lead to confusion and that to obviate this confusion it was desirable to substitute the other name *Mungo*.

"As a merely bibliographical matter then the decision of Trimen to revert to the name *P. max* (1753) which was intended to signify the same species as the *P. mungo* of 1767 had apparently full justification. But it does not seem desirable to follow Trimen owing to the fact that, though *P. max* was intended to signify the Mung crop, in reality the plant described and represented by the Linnæan types is the 'Soy' crop.

"However, while I am able to tell you the whole story I am fortunately able to leave to you the responsibility of deciding what to do about the 'names.'

"Yours very truly,

(Signed) "D. PRAIN."

While it is a matter of satisfaction to clear up so interesting a point regarding the botanical history of an important plant, it is always a disagreeable duty to change names which have become well established by long usage in literature. In this case, however, such a change is unavoidable. The fact that the name *Phaseolus max* belongs to the soy bean makes it necessary to revise the botanical designation of the latter plant. Inasmuch as the specific name *max* as applied to the soy bean appears on a previous page to the name *soja,* it has priority according to all botanical codes and hence must be adopted as the specific botanical name of the soy bean.

In most botanical works the soy bean is called *Glycine hispida* (Moench) Maximowicz. By a few writers it is named *Soja hispida* Moench. The use of either of these names is based on the idea that the wild soy bean *Glycine soja* Siebold and Zuccarini or *Glycine ussuriensis* Regel and Maack is a different species. As Piper and Morse (Bureau of Plant Industry, Bul. 197), have shown, this view is untenable, the wild and the cultivated plants representing but one species. The cultivated plant was first named *Dolichos soja* L. (Species Plantarum, 2: 727, 1753), but as the specific name *soja* was used later by Siebold and Zuccarini for the wild plant, it has since been generally used in that sense. With the recognition of the fact that there is but one species and not two the name *Glycine soja* (L.) Siebold and Zuccarini designates the cultivated as well as the wild plant. But the specific name *soja* must now give way to that of *max.*

Unfortunately there is also question as to the proper generic name to be attached to the soy bean. Nearly all botanists have used the name *Glycine* for the genus containing the soy bean and related species, but a few have used *Soja. Soja* was proposed by Moench in 1794 and included only the soy bean.

Linnæus in using the name *Glycine* in the Species Plantarum, 1753 cites Apios of Boerhaave as a synonym. He describes 8 species as follows:

1. *Apios* = *Apios tuberosa.*
2. *frutescens* = *Kraunhia frutescens.*
3. *abrus* = *Abrus precatorius.*
4. *tomentosa* = *Rhynchosia tomentosa.*
5. *comosa* = *Amphicarpæa comosa.*
6. *javanica* = *Glycine javanica.*
7. *bracteata* = *Amphicarpæa bracteata.*
8. *bituminosa* = *Fagelia bituminosa.*

As will be seen all of the original species of *Glycine* have been removed from the genus but one, *Glycine javanica,* which by the method of elimination would be the type species of the genus *Glycine.* While in this particular case the method of elimination works very nicely, there are numerous other cases in which it leads into hopeless difficulties.

Inasmuch as Linnæus cites *Apios* of Boerhaave as a synonym of *Glycine,* some recent botanists have considered that *Glycine* should be used in that sense and hence have employed it in preference to *Apios* for the plant described by Boerhaave, namely, the American wild bean or groundnut. This seems clearly to be the idea in Linnæus's mind. If *Glycine* be thus used the next available name for the soy bean genus is *Soja* of Moench, published in 1794. Following this interpretation the soy bean must be named *Soja max* (L.).

A NEW METHOD OF GROWING CORN.

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A new method of planting corn under dry-land conditions has been developed in western Kansas, which is giving remarkable increases in yield over corn planted in the ordinary way. It is known as the double-spacing method. The difference between this and the usual way of planting is that every other row is left vacant; that is, the rows are planted seven feet apart instead of the usual distance of three and one half feet. The vacant rows are listed out (corn is planted with a lister in western Kansas) and are given the same cultivation during the season as the planted rows.

Mr. A. T. Patterson, of Goodland, Kansas, was the first person to practice the double-spacing method of growing corn. He began growing corn in this way in 1910. The writer knows of no other party planting corn by this method prior to 1912. It is claimed by Mr. Patterson that the double-spaced method gave much better results than the ordinary method in 1910 and 1911, but comparative data are not available for these seasons. In 1912 the writer visited a forty-acre field of corn grown by Mr. Patterson in which the rows were double spaced. As compared with other corn in the locality planted by ordinary methods, it was a pleasing sight. Practically every stalk was fully developed and had produced a good ear of corn. The field would easily make thirty bushels per acre, which is a heavy yield of corn for that section of Kansas. Adjoining fields in which the rows were three and one half feet apart would not yield more than ten to twelve bushels per acre.

In 1913 the double- and single-spacing methods of planting corn were accurately compared at the Tribune substation of the Kansas Experiment Station, which is located at Tribune, Greeley County. The experiment was conducted on upland silt loam soil characteristic of western Kansas. The corn grown by the double-spacing method produced sixteen bushels of ear corn and twelve hundred pounds of stover per acre, while that planted in every row failed to produce grain and yielded only one thousand pounds of stover. Practically equivalent stands of corn were obtained for the two methods of planting under comparison. The hills in the single-spaced rows were thirty-six inches apart, while the distance between hills for the double-spaced rows was only eighteen inches. Evidently factors other than that of stand were responsible for the difference in yields obtained.

In growing corn in the western portion of Kansas, the greatest problem to overcome is to keep the crop in a flourishing condition throughout temporary periods of drouth, which usually occur during July and August. Corn, unlike kafir and other sorghums, is incapable of going into a dormant condition during dry periods and then starting development again when conditions become favorable for growth. It dries up and dies, or, if the drouth is not too severe, partially fires and remains alive during its normal growing period, but fails to develop grain. The problem then is to provide moisture in such a way that it will be available throughout the entire growing period. It appears that this is brought about to a considerable extent by the double-spacing method of planting corn.

The supply of moisture is not increased in any way, but the utilization of that available is so governed that it is used to better advantage.

The greater efficiency in the use of moisture is brought about by the spacing of the corn plants. For instance, when the desired rate of planting, where corn is planted in every row, is thirty inches per hill, to obtain an equivalent stand per acre when the double-spacing method is employed, necessitates a fifteen-inch rate of planting. Figs. 3 and 4 illustrate the relative spacing of the hills of corn for the two methods.

Where corn is planted by the single-spacing method (Fig. 3), the roots occupy the entire soil space when they become 26 inches in length and competition for plant food and moisture between plants in the row begins when the roots obtain a length of 15 inches.

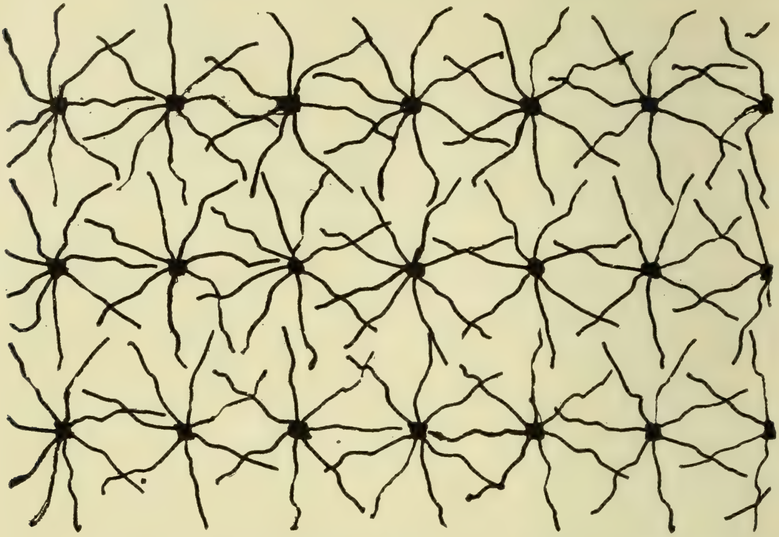

Fig. 3.—Showing the arrangement of hills of corn where the rows are single-spaced, the rate of planting being one kernel every thirty inches. The dots represent the stalks and the radiating lines the extent of the root system at a period when the roots are about 25 inches in length.

Where the double-spacing method of planting corn is employed (Fig. 4) the competition betwen plants for moisture and plant food begins when the roots become seven and one half inches in length, and the soil space is not entirely occupied by roots until they become about forty-three and one half inches in length. These figures represent only the lateral distribution of the roots. If the soil was moist to a depth of four feet, then the entire soil space from which moisture would be available would not be occupied until the corn roots obtained a length of nearly four and one half feet for the single-spaced rows, and nearly 6 feet for double-spaced. Because of the wider spacing for the latter method, the moisture and plant food midway between the rows, especially that in the deep subsoil, is held in reserve for the later stages of growth, which is always the critical period in the development of the corn plant. During temporary periods of drouth, this reserve supply of moisture is often sufficient to maintain the corn in a flourishing condition until rains come, while occasionally it may complete the development of the crop.

The double spacing of the rows would not be so effective in bringing about a more efficient utilization of moisture if it were not for the fact that where the corn is planted by this method competition for moisture and plant food between plants in the row begins sooner than for the single-spacing method, since the distance between plants is only half as great. Because of the earlier competition, the corn plants do not obtain moisture and plant food so abundantly during the early stages of growth and, therefore, do not make as great a development of foliage as when the plants are farther apart in the row, which is the condition with the single-spaced method.

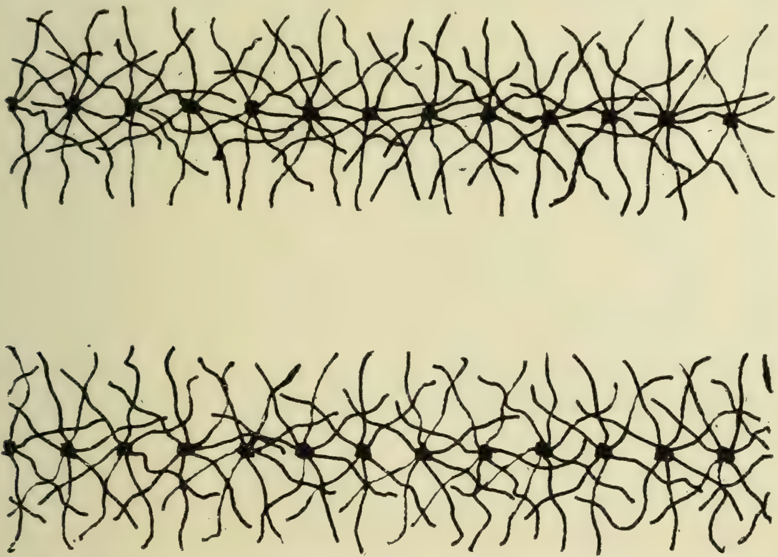

FIG. 4.—Showing the arrangement of the hills of corn as they would have to be planted, when the double-spacing method is employed, in order to obtain a stand equivalent to a thirty-inch rate of planting for the single-spaced method. The roots are the same length as those in Fig. 3.

The plants developing less foliage do not require as much moisture to reach maturity as those making a larger growth, hence they have the advantage in producing grain where moisture during the latter part of the season is the limiting factor.

There are several advantages in cultivation that should make the double-spacing method of planting popular, even though no increases in yield resulted. The weeds most difficult to control are those that come up in the row near or on a line with the corn. Since only half as much row space is planted the liability of trouble from this source is reduced fifty percent. In cultivating the corn, the two-row cultivator may be used, straddling the rows in the same manner that the one-row implement is employed in going over single-spaced corn. This does away with the necessity of trying to watch two rows at the same time when the two-row cultivator is used. Also the two-row cultivator may be used without trouble in cultivating corn planted by a single-row lister. Corn planted in the ordinary way with a single-row lister cannot be cultivated to a good advantage with the two-row implement unless the rows are uniformly spaced, which requires more careful planting than is ordinarily obtained. With the double-spacing method it is not so essential to make the rows the same distance apart. After the corn becomes too high to cultivate by straddling the rows, implements requiring only 2 horses may be used in cultivating double-spaced corn. This is a great advantage, for the work can be accomplished much more rapidly and at less expense than it could be done if it were necessary to use comparatively narrow implements drawn by one horse.

It is the writer's opinion that good results can be obtained by double spacing kafir and other grain sorghums grown under semi-arid conditions, although the percent increase in yield of grain would probably not be so great as with corn. These crops have the ability to remain dormant during periods of drouth, and the problem of maintaining growing conditions through the period of development is not so important.

AGRONOMIC AFFAIRS.

AGRONOMY AND BOTANY.

This issue of the JOURNAL contains an article which is entirely botanical in content. Furthermore, its botany is historical botany in the main, though with a mild taxonomic flavor. The article in question was accepted by the editor with a full knowledge of its nature. This does not indicate in any way a change in the character of the JOURNAL but it does invite consideration of the relations of agronomy and botany.

The boundary line between botany and agronomy always has been debatable, but always undebated. And why? Probably because of the very diverse sources from which agronomic workers have been recruited. So far as the older workers are concerned these sources are three in number. The agronomist is (1) the heir of the old-time agriculturist, often a farm-crop superstructure on a livestock foundation; or (2) he is a botanist transformed by pressure of circumstance into a worker with crops; or (3) he is a chemist who has entered the field by way of pot experiments and fertilizer tests.

The transferred agriculturist and chemist are not speculative about the botanical aspects of agronomy. Their path of approach has been from a different direction than that traversed by the botanist. They have arrived at a different side of the agronomic field and have seldom been tempted to survey its boundaries. On the other hand, the transformed (or reformed) botanist has not usually realized that he is away from home. These are probably some of the reasons why there has been but little thought of the interrelations between botany and agronomy.

If botany is the science of plants and their response to environment, then agronomy in its crop aspects is one of the specialized divisions of botany, coordinate with bacteriology, mycology, paleobotany, pharmacology, pomology, forestry,and others. Like these, agronomy, to be completely interpreted, must embrace all the factors of botany proper, namely, morphology (form), physiology (function), ecology (environment, including distribution) and taxonomy (relationship). To these four factors should be added a fifth, technology (use, or applied botany), too often neglected or studiously avoided by botanists. In the above outline ecology is obviously broad and includes comprehensive studies of the soil, as the environing substratum, and of climatology.

What is needed, therefore, is not an attempted separation of botany and agronomy but a recognition of the logical relation between them.

There is an element of truth in the old statement that no botanist would look at a cultivated plant while no crop student would touch a wild one. Any surviving remnant of this attitude on either side should give way to mutual appreciation. The botanist should study the cultivated relatives of the wild flora. In so doing he will certainly increase his ability to interpret the myriad forms of feral vegetation. He will discover, also, the greatly increased range of expression which plants acquire under domestication. From this he will come to appreciate that any given morphological differences do not have the same taxonomic values in cultivated plants as in wild ones. An earlier recognition of this fact might have prevented the confusing synonomy in specific names applied to wheats, sorghums, and other crop plants.

On the other hand, the crop student will benefit by using the more exact methods of the botanist in separating varieties and selections. In this he will have need for a full knowledge of morphology, especially that relating to the inflorescence and fruit. Nor should he neglect the study of the wild species related to his crops. Such a study will not only give him a better knowledge of the origin and character of the domesticated forms but may enable him to discover and domesticate others equally valuable for certain conditions and purposes.

MEMBERSHIP CHANGES.

The 372 members reported in the last issue, less 1 resigned, and plus 20 new members, places the present membership of the Society at 391. Sample copies of the Journal will be sent gladly to any nonmembers whose names may be furnished us by members at any time. The membership should be increased to 400 and over before summer. This probably will require about 20 more new members, as some will allow their membership to lapse on April 1, through nonpayment of dues.

Members Resigned.

Dodson, W. R.

New Members.

Arny, A. C., St. Anthony Park, Minn.
Ballard, Robert L., Coöperative Demonstration Work, Ashburn, Ga.
Bonazzi, Augusto, Experiment Station, Wooster, Ohio.
Brunson, A. M., Experiment Station, Urbana, Ill.
Dickenson, Robert W., Experiment Station, Urbana, Ill.
Dobbs, W. Frank, American Coal Products Co., Athens, Ga.
Doneghue, R. C., Agricultural College, N. Dak.
Fox, D. S., Dept. Farm Management, Cornell Univ., Ithaca, N. Y.
Fred, Edwin Brown, College of Agriculture, Madison, Wis.

Gentle, G. E., Experiment Station, Urbana, Ill.
Gile, Philip L., Experiment Station, Mayaguez, Porto Rico.
Grantham, Geo. M., Experiment Station, Urbana, Ill.
Keim, Frank D., University Farm, Lincoln, Nebr.
Kinnaird, R. A., Agricultural College, Columbia, Mo.
McMurdo, George A., Experiment Farm, Akron, Colo.
Olson, M. E., Branch Expt. Station, Route 3, Ames Iowa.
Peters, David C., 7th Avenue, Kaimuki, Honolulu, Hawaii.
Pope, M. N., Agricultural College, N. Dak.
Westbrook, E. C., State College of Agriculture, Athens, Ga.
Yoder, Malon, College of Agriculture, O. S. U., Columbus, Ohio.

Addresses Changed.

Ball, Wilbur M., Ministerio de Agricultura, Buenos Aires, Argentina, S. A
Brown, C. B., Experiment Station, Dalhart, Texas.
McFetridge, Wm. L., R. R. 4, Oshkosh, Wis.
Madson, B. A., University Farm, Davis, Cal.
Napier, J. M., Columbia, S. C.
Newton, Robert, Woodstock, New Brunswick, Canada.
Oakland, Irwin, Sioux Falls, S. Dak.
Ten Eyck, A. M., Winnebago Co. Farm Improvement Assoc., Rockford, Ill.

NOTES AND NEWS.

Dr. George N. Coffey, of the Ohio Experiment Station, delivered lectures before the short course students at Louisiana University in January.

Mr. C. R. Ball, of the U. S. Office of Cereal Investigations delivered three lectures before the Short Course Students at the Oklahoma Agricultural College on January 14 and 15.

Mr. P. V. Cardon, in charge of the tillage and rotation work conducted by the U. S. Office of Cereal Investigations in the Great Basin and Pacific Coast areas, transferred on February 1 to the Office of Acclimatization and Adaptation of Crop Plants, where he will take up field investigations with cotton.

Prof. A. M. Ten Eyck, of the extension division of the Iowa Agricultural College, has accepted the position of agricultural advisor for the Farm Improvement Association of Winnebago County, Illinois, with headquarters at Rockford. Prof. Ten Eyck is the author of a book entitled "Wheat," which has just appeared from the press of the Campbell Soil Culture Publishing Company, Lincoln, Nebraska.

Prof. George Livingston, of the Ohio State University, who has spent a part of his year's leave of absence in research work at Cornell University, sailed on March 28 to take up studies abroad. He will spend the summer semester at the University of Halle, taking up work in plant breeding and farm crops. Prof. Livingston is joint author of a laboratory manual in agronomy which appeared some months ago.

Dr. T. Lyttleton Lyon, chief of the department of soil technology of Cornell University, has returned from a four months' tour of scientific institutions in European countries. There appears in this issue his report of the meeting of the International Commission for the Mechanical and Physical Examination of Soils, which he attended while in Berlin.

Mr. Clyde McKee, assistant professor of farm crops at the Iowa Agricultural College, is one of the two members of the staff selected to teach that subject at the summer school for high school and rural school teachers which follows the close of the regular college year.

Field Station Men of U. S. Bureau of Plant Industry.

The following members of the Society, who are connected with the field stations of the Bureau of Plant Industry, and have spent some portion of the winter in Washington, engaged in laboratory studies and the preparation of annual reports, have returned to their respective stations:

Office of Cereal Investigations,—L. C. Aicher, F. R. Babcock, J. Allen Clark, N. C. Donaldson, J. W. Jones, G. A. McMurdo, J. D. Morrison, J. F. Ross, T. R. Stanton and Louis Wermelskirchen;

Office of Dry Land Agriculture,—C. B. Brown, E. F. Chilcott, J. S. Cole, W. D. Griggs, A. L. Hallsted, G. W. Morgan, and L. D. Willey;

Office of Forage Crop Investigations,—A. B. Cron, M. W. Evans, Samuel Garver, and R. E. Getty;

Office of Alkali and Drought Resistant Plant Breeding Inv.,—A. C. Dillman.

Meeting of the New England Agronomists.

On December 13, 1913, a meeting of the agronomists connected with the New England Agricultural Colleges and Experiment Stations, was held in Boston. There were present:

New Hampshire: F. W. Taylor.

Massachusetts: J. A. Foord, S. B. Haskell, and E. M. McDonald.

Connecticut: W. L. Slate, Jr., and B. G. Southwick.

Rhode Island: G. E. Adams, and also Dr. H. J. Wheeler, formerly director of that station.

The meeting took the form of a luncheon with a discussion following. No permanent organization was affected but W. L. Slate, Jr., was elected secretary with the power to call future meetings. As was anticipated, the discussions were along the line of teaching methods and the possibilities for cooperation among workers who have many problems in common.

SPECIAL MEETING AT DALLAS, TEXAS.

The special meeting of the Society planned to be held on February 18 during the Sixth National Corn Exposition, at Dallas, Texas, was called to order at 7:30 p. m. on that date, at the Oriental Hotel, Vice-President E. G. Montgomery presiding. On motion professor Alvin Keyser was made Secretary pro tem.

The following papers were then presented:

1. "Breeding, Testing, and Distributing Improved Seed Grain in North Dakota," by W. R. Porter.
2. "Mendelian Inheritance in Wheat, Oat and Barley Hybrids" (illustrated), by E. F. Gaines.
3. "Relation of Yield of Straw and Grain in Oats" (illustrated), by H. H. Love.
4. "Some Rhode Island Soil Conditions," by H. J. Wheeler.

Full and interesting discussion followed the papers. Thirty-five persons were in attendance.

MEETINGS OF THE WASHINGTON SECTION.

The local section organized at Washington last December has had a very successful winter. The section contains 71 members, of whom 45 are members of the parent society. Four regular meetings have been held. The average attendance at these meetings was 44.

The proceedings of the first meeting, which was held in December, were reported in No. 4, of Volume 5, of the JOURNAL. At the January meeting consideration was given to the subject, "Factors Influencing the Spacing of Field Crops." A general outline of the subject was presented by Mr. C. S. Scofield, and papers were read as follows:

"Grain Sorghum," by Mr. C. R. Ball.

"Cotton," by Mr. R. M. Meade.

"Corn," by Mr. L. L. Zook.

"Wheat," by Mr. P. V. Cardon.

"Alfalfa," by Mr. R. A. Oakley.

At the third meeting, which was held February 17, the general topic was "The Physical Basis of Tillage for Field Crops." Dr. L. J. Briggs read a paper outlining the subject in general, and different phases of the subject were discussed as follows:

"Moisture Conservation in the Great Plains as Affected by Spring and Fall Plowing and Summer Tillage," by Mr. J. C. Thysell.

"The Relation of Tillage to Run-Off," by Mr. C. R. Letteer.

"Evaporation as Modified by Tillage in the Great Basin," by Mr. L. C. Aicher.

At the fourth regular meeting, which was held March 13, the following papers were read:

"Measuring the Comparative Drought Resistance of Alfalfa Varieties" (with lantern), by Mr. A. C. Dillman.

"Present Day Practices and Problems in the Sugar Cane Syrup Industry" (with lantern), by Dr. P. A. Yoder.

At each of the four meetings, the program was followed by a social hour.

MEETING OF THE INTERNATIONAL COMMISSION FOR THE MECHANICAL AND PHYSICAL EXAMINATION OF SOILS.

At the second international agrogeological conference held in Stockholm in 1910 there was appointed a commission to study and report on methods for the mechanical and physical examination of soils. The last meeting of this commission was held on October 31, 1913, in the Royal Geological Institute in Berlin.

A. Atterberg, director of the agricultural experiment station at Kalmar, Sweden, who is chairman of the commission, demonstrated his proposed method for the mechanical analysis of soils. Those present at the meeting, including members and guests were as follows:

Professor R. Albert, Eberswalde, Germany.
Director Alb. Atterberg, Kalmar, Sweden.
Dr. E. Blanck, Breslau, Germany.
Dr. Theod. de Almeida Camargo, Brazil.
Professor R. Gans, Berlin, Germany.
Director B. Heinitz, Pisck, Bohemia.
Director D. J. Hissink, Wageningen, Holland.
Dr. S. Johansson, Kalmar, Sweden.
Professor T. L. Lyon, Ithaca, N. Y., U. S. A.
Dr. R. Muenk, Berlin, Germany.
Professor E. Ramann, Munich, Germany.
Dr. F. Sucht, Berlin, Germany.
Professor Alexius de'Sigmond, Budapest, Bohemia.
Professor F. Wahnschaffe, Berlin, Germany.

After hearing the report by Dr. Atterberg, the commission listened to the reading of communications from various members of the commission regarding the matter in hand. This was followed by an oral discussion of the subject and the adoption of certain definite recommendations by the commission, which are stated below.

"1. The use of division of particles propsed by Dr. Atterberg, and which is as follows:

				Size of Particles.
Particles greater than			20	mm.
Particles from	20	to	2	mm.
Particles from	2	to	0.2	mm.
Particles from	0.2	to	0.02	mm.
Particles from	0.02	to	0.002	mm.
Particles finer than			0.002	mm.

"2. The creation of subdivisions of these main groups shall not now be attempted.

"3. Further study should be made of the best methods for the preparation of the soil for the mechanical analysis. The use of shaking as compared with rubbing the soil for this purpose should be investigated. The soil should pass through a sieve having perforations 2 mm. in size. The use of acid and of alkali in preparing the soil should be avoided if possible. For humus soils special methods must be devised.

"4. The apparatus of Atterberg (see Internationale Mitt. f. Bodenk. 1912, page 319) shall be taken as the standard. Round hole sieves shall be used. The use of the sieve is recommended for the separation of particles only to 0.5 mm. in size.

"5. Further investigation is necessary to determine how the colloidal matter may best be collected and weighed. For soils rich in clay the determination of colloidal matter by difference is permissible. For soils poor in clay the content of clay requires the direct determination.

"6. The humus content shall be determined through a carbon estimation acording to the method of elementary analysis. The carbon found shall be stated and humus content expressed by multiplying the CO_2 found by 0.5, *i. e.*, humus content $= CO_2 \times 0.5$.

"7. Comparative tests shall be made by members of the commission of the method proposed by Hissink, of shaking the soil to prepare it for analysis and the method of Atterberg of rubbing it. Samples for such purpose will be sent out by Dr. Atterberg."

It will be seen that this is a feature of the attempt to standardize the fundamental methods of soil classification, the need for which is so apparent in the Enropean countries. The importance of doing this at the outset of soil survey work is apparent.—T. Lyttleton Lyon, Department of Soil Technology, Cornell University, Ithaca, N. Y.

COMING EVENTS.

Under this caption it is proposed to keep a standing schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

American Society of Agronomy.

Special Meeting, Hays, Kan., July 8–10, 1914, in connection with the meeting of the Great Plains Cooperative Association.

American Association for the Advancement of Science.

Philadelphia, Pa., Convocation Week, 1914–15.

American Society of Milling and Baking Technologists.

Annual Meeting, Washington, D. C., November, 1914 (in connection with the Association of Official Agricultural Chemists).

Association of Official Agricultural Chemists.

Annual Meeting, Washington, D. C., November, 1914.

Graduate School of Agriculture.

University of Missouri, Columbia, Mo., June 29 to July 25, 1914. Conferences on Methods of Instruction in Agronomy:

(*a*) Soils, Wednesday, July 15, 8 p. m.
(*b*) Crops, Friday, July 17, 8 p. m.

Great Plains Cooperative Association.

Hays Branch Station, Hays, Kan., July 8–10, 1914.

International Dry Farming Congress.

Annual Session, Wichita, Kan., October 7–17, 1914.

LOCAL SECTIONS.

Cornell University and Experiment Station.

President, Millard A. Klein.
Secretary,——————————.

Kansas Agricultural College and Experiment Station.

President, W. M. Jardine.
Secretary-Treasurer, C. C. Cunningham.

Washington, D. C.

President, W. W. Burr.
Secretary-Treasurer, F. D. Farrell.

JOURNAL

OF THE

American Society of Agronomy

VOL. 6 MAY–JUNE, 1914 NO. 3

RELATION OF YIELD OF STRAW AND GRAIN IN OATS.[1]

H. H. LOVE.

The question of the relation of straw to grain in small grains has been discussed to some extent in various publications.

Scherffius and Woosley[2] report the yields of straw and grain in a three years' test of thirty-one varieties of wheat at the Kentucky Experiment Station. They conclude "that there is no absolute relation between the yield of straw and grain, but that, generally, the highest yields of straw are associated with low yields of grain under normal conditions." Myers[3] has shown that for individual culms of wheat there is a high correlation between total weight of culm and weight of grain.

While conducting a large number of variety and strain tests of oats at the Cornell Agricultural Experiment Station the question arose whether there is a close relationship between yield of grain and yield of straw or whether these two factors occur independently.

The yield of straw is a very important consideration in selecting an oat variety. In the eastern states where straw is more valuable than it is in the great oat-growing sections it is very important to have a variety giving both a high yield of straw and grain. In other localities it is important to obtain as near a balance as possible between straw and grain.

While conducting these variety tests the yield of straw has been taken for the three years, 1911, 1912 and 1913. This yield has been obtained by subtracting the weight of grain from the total weight

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[1] Paper No. 47, Department of Plant-Breeding, Cornell University, Ithaca, N. Y. (Received for publication in May, 1914.)

[2] Scherffius and Woosley, Wheat, Ky. Expt. Sta. Bull., 135.

[3] Myers, C. H., Effect of Fertility upon Variation and Correlation in Wheat, Proc. Am. Breeders' Assoc., 7: 61–74, 1912.

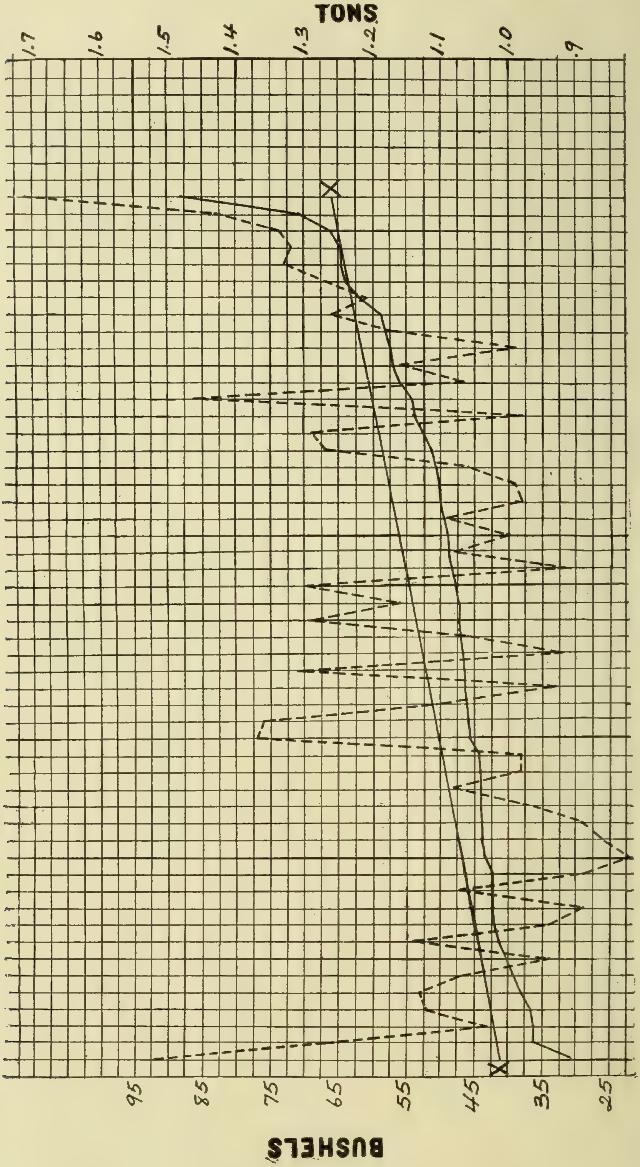


Fig. 5.—Relation between yield of grain and yield of straw in oats for 1911. Solid line grain and broken line straw; XX, fitted straight line.

before threshing; the difference is the weight of straw and chaff. These weights are then calculated to tons per acre and are thus expressed.

From the results it was evident that certain varieties are naturally low in straw production while others are high. Certain varieties may be selected which produce a large amount of straw and a small amount of grain, while on the other hand there are those which produce a

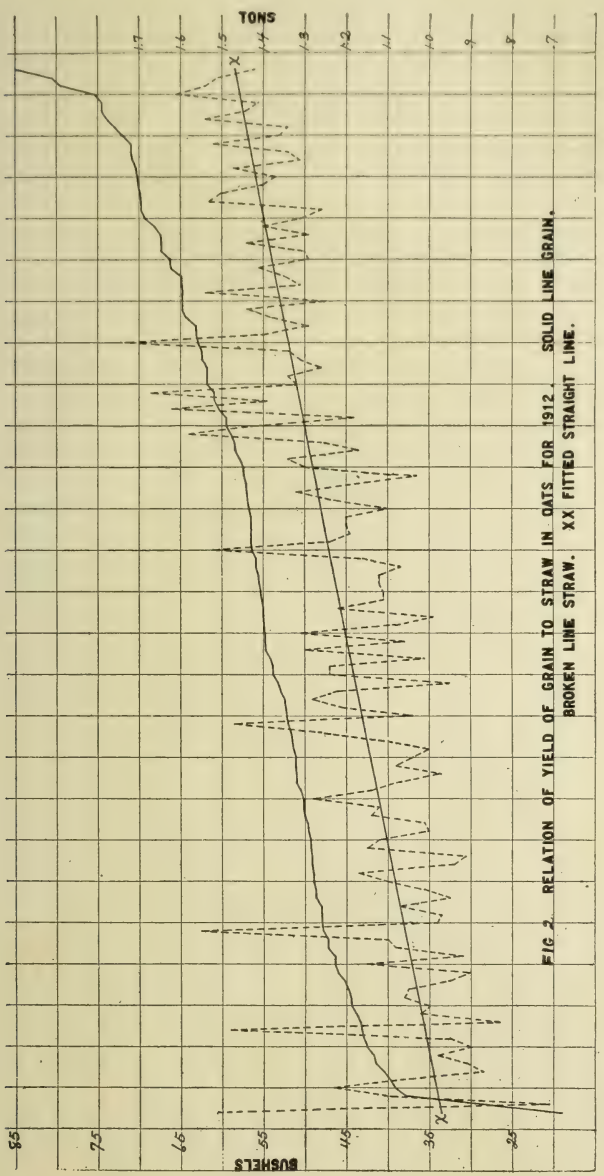
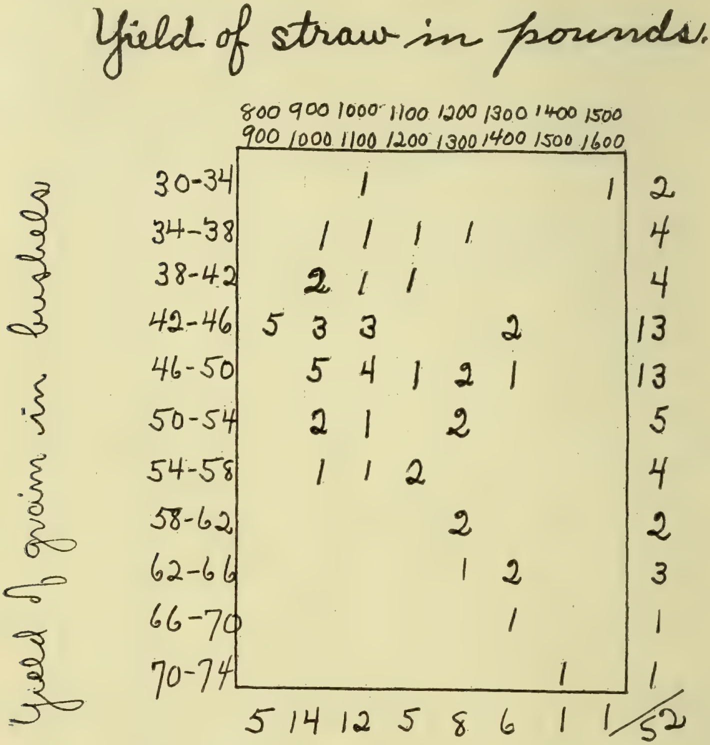


FIG. 6.—Relation of yield of grain to straw in oats for 1912. Solid line grain; broken line straw; XX fitted straight line.

large amount of grain with a relatively small amount of straw. While such instances may occur the question is whether as a general rule there is a relationship between yield of straw and grain.

By selecting such isolated cases as above mentioned, one might conclude that there is no relationship between the yield of grain and straw. This, however, is not the correct method of determining whether there is any relation between these two characters. This relation is better illustrated by Figs. 5 and 6, which represent the yield of grain in bushels per acre and the yield of straw in tons for all varieties grown in 1911 and 1912.



Yield of straw in pounds.

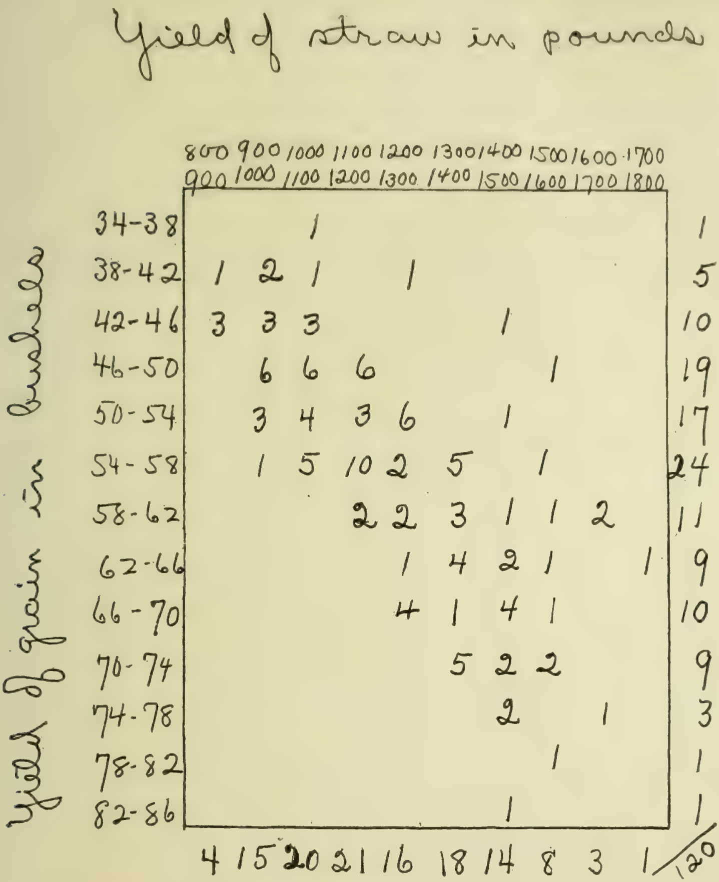
Yield of grain in bushels

	800 900	900 1000	1000 1100	1100 1200	1200 1300	1300 1400	1400 1500	1500 1600	
30-34			1					1	2
34-38		1	1	1	1				4
38-42		2	1	1					4
42-46	5	3	3			2			13
46-50		5	4	1	2	1			13
50-54		2	1		2				5
54-58		1	1	2					4
58-62					2				2
62-66					1	2			3
66-70						1			1
70-74							1		1
	5	14	12	5	8	6	1	1	52

FIG. 7.—Correlation between yield of straw and grain for 1911. $r = .357 \pm .082$.

These charts are arranged as follows: the yield of grain in bushels is plotted in ascending order and these points are connected by the solid line, thus showing graphically the yield of grain in order from the lowest to the highest. The yield of straw in tons per acre for each variety is plotted on the ordinate corresponding to its respective grain yield.

The relation is well illustrated by means of the straight lines which have been fitted by the method of least squares to the points representing the straw yields. The straight lines have a decided tendency to slope upward thus in each case showing that as the varieties tend to increase in yield of grain there is also an increase in yield of straw. The few cases which do not agree with this general conclusion are brought out very plainly in this graphic manner.



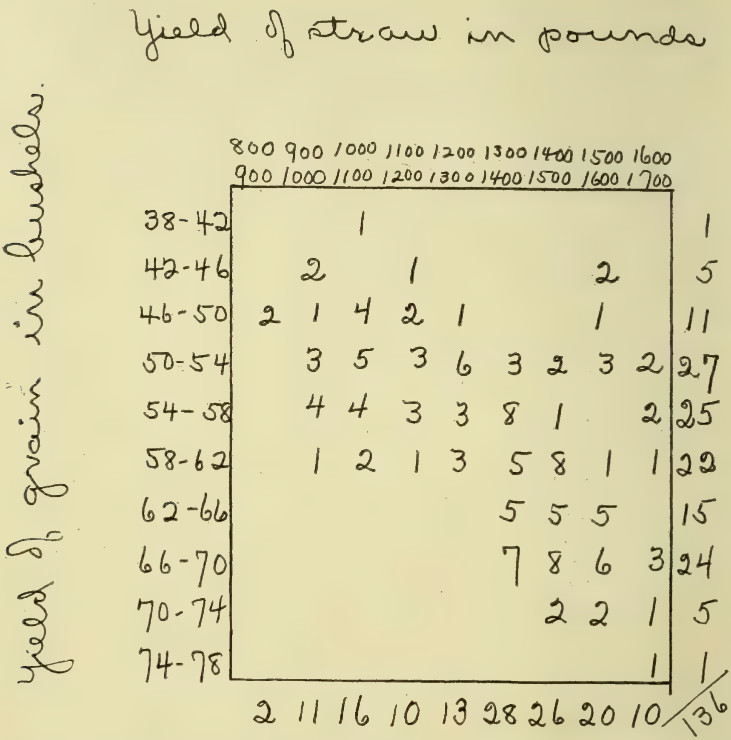
Yield of straw in pounds

Yield of grain in bushels	800 900	900 1000	1000 1100	1100 1200	1200 1300	1300 1400	1400 1500	1500 1600	1600 1700	1700 1800	
34-38			1								1
38-42	1	2	1		1						5
42-46	3	3	3				1				10
46-50		6	6	6				1			19
50-54		3	4	3	6		1				17
54-58		1	5	10	2	5		1			24
58-62				2	2	3	1	1	2		11
62-66					1	4	2	1		1	9
66-70					4	1	4	1			10
70-74						5	2	2			9
74-78							2		1		3
78-82								1			1
82-86							1				1
	4	15	20	21	16	18	14	8	3	1	120

FIG. 8.—Correlation between yield of straw and grain for 1912. $r = .714 \pm .030$.

Another method of measuring this relationship between the yield of grain and the yield of straw is by means of correlation tables. These tables have been made and the correlation calculated for the three years, 1911, 1912 and 1913. The tables are illustrated in Figs. 7, 8 and 9.

The correlation coefficients for the three years are .357 ± .082, .714 ± .030 and .500 ± .043, which show that there is a very good correlation between the two characters in question. It may be stated that one may expect the yield of grain to be proportional to yield of straw and that in general for the locality in which the test was made varieties which produce a good yield of straw will also produce a good amount of grain.



Yield of straw in pounds

Yield of grain in bushels

	800	900	1000	1100	1200	1300	1400	1500	1600	
	900	1000	1100	1200	1300	1400	1500	1600	1700	
38-42			1							1
42-46		2		1				2		5
46-50	2	1	4	2	1			1		11
50-54		3	5	3	6	3	2	3	2	27
54-58		4	4	3	3	8	1		2	25
58-62		1	2	1	3	5	8	1	1	22
62-66						5	5	5		15
66-70						7	8	6	3	24
70-74							2	2	1	5
74-78									1	1
	2	11	16	10	13	28	26	20	10	136

FIG. 9.—Correlation between yield of straw and grain for 1913. $r = .500 \pm .043$.

Another important consideration in connection with the yield of straw is the ratio of straw to grain; or, in other words, how much straw is required to produce a pound of grain for the different varieties. This is important, for in some localities straw is not so valuable and also it may often be better to use those varieties requiring a relatively small amount of straw to produce a pound of grain. The ratio of straw to grain has been calculated by dividing the pounds of straw by the pounds of grain; for example, the yield of the Sixty Day for 1911 was 1,478.4 pounds of grain and 1,862 pounds of straw; $\frac{1862.0}{1478.4}$

TABLE 1.—*Showing Weights of Straw and Grain of Oat Strains in Pounds per Acre, and Ratio of Straw to Grain for 1911, 1912, and 1913; Arranged in Ascending Order of the Ratio for 1911.*

	1911.			1912.			1913.		
	Wt. of Grain Lbs. per Acre.	Wt. of Straw Lbs. per Acre.	Ratio Lbs. of Straw to Lbs. of Grain.	Wt. of Grain Lbs. per Acre.	Wt. of Straw Lbs. per Acre.	Ratio Lbs. of Straw to Lbs. of Grain.	Wt. of Grain Lbs. per Acre.	Wt. of Straw Lbs. per Acre.	Ratio Lbs. of Straw to Lbs. of Grain.
62–II–18–3	1,836.8	1,984	1.08 : 1	1,734.4	2,028	1.17 : 1	1,526.4	1,976	1.29 : 1
62–II–18–1–1	1,724.7	1,954	1.13 : 1	1,702.4	1,908	1.12 : 1	....	.....	......
34*a*1–28–2	1,385.6	1,636	1.18 : 1	1,385.6	1,652	1.19 : 1	1,472.0	1,856	1.26 : 1
62–II–6–3	1,545.5	1,816	1.18 : 1	1,360.0	1,798	1.32 : 1	....	.....	......
50*a*1–10	1,795.2	2,146	1.20 : 1	1,753.6	2,112	1.20 : 1	1,900.8	1,994	1.05 : 1
125–20	2,828.8	3,416	1.21 : 1	2,332.8	2,676	1.15 : 1	2,182.4	2,666	1.22 : 1
49*a*2–22	1,600.0	1,954	1.22 : 1	1,587.2	2,010	1.27 : 1	....	.....	......
120–9	1,983.9	2,424	1.22 : 1	2,153.6	2,598	1.21 : 1	2,224.0	2,790	1.25 : 1
34*a*1–27–2	1,395.2	1,722	1.23 : 1	1,571.2	1,876	1.19 : 1	....	.....	......
62–II–6–2	1,606.4	1,978	1.23 : 1	1,328.0	1,818	1.37 : 1	1,481.6	1,746	1.18 : 1
62–II–17–1	1,491.2	1,838	1.23 : 1	1,372.8	1,908	1.39 : 1	....	.....	......
123–5	2,048.0	2,546	1.24 : 1	2,233.6	2,528	1.13 : 1	2,204.8	2,730	1.24 : 1
34*a*1–11–2	1,859.2	2,338	1.26 : 1	1,833.6	2,054	1.12 : 1	1,977.6	2,108	1.07 : 1
Great American P. B. 1573	2,118.3	2,674	1.26 : 1	2,217.6	2,622	1.18 : 1	2,176.0	2,846	1.31 : 1
Sixty Day P. B. 1574	1,478.4	1,862	1.26 : 1	1,334.4	1,964	1.47 : 1	1,520.0	1,748	1.15 : 1
Silvermine P. B. 1571	2,262.4	2,866	1.27 : 1	2,121.6	2,580	1.22 : 1	2,281.6	2,890	1.27 : 1
50*a*1–22	1,827.2	2,314	1.27 : 1	1,760.0	1,972	1.12 : 1	1,734.4	1,982	1.14 : 1
132–2	1,395.2	1,774	1.27 : 1	1,571.2	1,830	1.16 : 1	....	.....	......
49*a*2–18	1,561.5	2,006	1.28 : 1	1,779.2	2,234	1.26 : 1	1,750.4	2,140	1.22 : 1
S. P. I. 21385 (Silvermine)	2,073.6	2,644	1.28 : 1	1,948.8	2,790	1.43 : 1	2,128.0	2,884	1.35 : 1
Twentieth Century P. B. 1576	2,070.4	2,662	1.29 : 1	2,265.6	2,618	1.16 : 1	2,163.2	2,890	1.34 : 1
27*a*1–31	1,625.6	2,118	1.30 : 1	2,076.8	2,612	1.26 : 1	2,169.6	2,622	1.21 : 1
34*a*1–27–3	1,353.6	1,786	1.32 : 1	1,590.4	2,022	1.27 : 1	1,628.8	2,036	1.25 : 1
34*a*1–24	1,347.2	1,786	1.33 : 1	1,398.4	2,048	1.46 : 1	1,625.6	1,940	1.19 : 1
Lincoln	1,884.7	2,512	1.33 : 1	2,252.8	2,938	1.30 : 1	2,246.4	3,210	1.43 : 1
5938–1	1,584.0	2,186	1.38 : 1	1,766.4	2,220	1.26 : 1	1,782.4	1,848	1.04 : 1
30*a*2–12–3	1,401.6	1,948	1.39 : 1	1,638.4	2,170	1.32 : 1	1,932.8	2,378	1.23 : 1
34*a*1–32–1	1,404.8	1,954	1.39 : 1	1,296.0	1,740	1.34 : 1	....	.....	......
49*a*1–27–1	1,414.4	1,960	1.39 : 1	1,670.4	2,080	1.25 : 1	1,654.4	2,030	1.23 : 1
49*a*2–20	1,555.1	2,158	1.39 : 1	1,577.6	2,246	1.42 : 1	....	.....	......
49*a*2–16–10	1,344.0	1,880	1.40 : 1	1,558.4	1,908	1.22 : 1	1,497.6	2,198	1.47 : 1
49*a*2–13	1,504.0	2,118	1.41 : 1	1,632.0	2,164	1.33 : 1	....	.....	......
31*a*1–16–1	1,286.4	1,890	1.47 : 1	1,510.4	2,164	1.43 : 1	1,702.4	2,328	1.37 : 1
Early Champion P. B. 1572	1,472.0	2,192	1.49 : 1	1,270.4	2,144	1.69 : 1	1,360.0	2,252	1.66 : 1
Danish Island	1,721.5	2,586	1.50 : 1	2,073.6	2,886	1.39 : 1	2,137.6	3,114	1.46 : 1
33*a*1–15	1,510.3	2,312	1.53 : 1	1,644.8	1,996	1.21 : 1	1,721.6	2,076	1.21 : 1
30*a*3–33	1,401.6	2,170	1.55 : 1	1,616.0	2,272	1.41 : 1	....	.....	......
Long's White Tartar P. B. 1568	1,641.6	2,540	1.55 : 1	1,993.6	2,618	1.31 : 1	2,176.0	3,106	1.43 : 1
42*a*1–1–2	1,347.2	2,146	1.59 : 1	1,568.0	2,196	1.40 : 1	1,510.4	2,090	1.38 : 1
131–19	1,740.8	2,928	1.68 : 1	1,808.0	2,394	1.32 : 1	1,782.4	2,252	1.26 : 1
Swedish Select P. B. 1575	1,529.6	2,592	1.69 : 1	1,974.4	2,650	1.34 : 1	1,811.2	2,770	1.53 : 1
32*a*2–1	1,257.6	2,146	1.71 : 1	1,510.4	2,208	1.46 : 1	1,548.8	2,140	1.38 : 1
Golden Giant Side	1,507.2	2,576	1.71 : 1	1,529.6	3,098	2.03 : 1	1,545.6	3,164	2.05 : 1
Welcome	1,327.8	2,286	1.72 : 1	1,808.0	2,484	1.37 : 1	1,840.0	2,854	1.55 : 1

	1911.			1912.			1913.		
	Wt. of Grain Lbs. per Acre.	Wt. of Straw Lbs. per Acre.	Ratio Lbs. of Straw to Lbs. of Grain.	Wt. of Grain Lbs. per Acre.	Wt. of Straw Lbs. per Acre.	Ratio Lbs. of Straw to Lbs. of Grain.	Wt. of Grain Lbs. per Acre.	Wt. of Straw Lbs. per Acre.	Ratio Lbs. of Straw to Lbs. of Grain.
30*a*2–1	1,158.4	2,054	1.77 : 1	1,577.6	2,246	1.42 : 1	......	.....	......
63–I–4	1,478.4	2,628	1.78 : 1	1,606.4	2,240	1.39 : 1	1,676.8	2,402	1.43 : 1
White Tartar King	1,216.0	2,262	1.86 : 1	1,673.6	2,426	1.45 : 1	1,916.8	2,684	1.40 : 1
Black Tartarian	1,465.5	2,720	1.86 : 1	1,664.0	2,944	1.77 : 1	1,788.8	3,348	1.87 : 1
Swedish Select P. B. 1599	1,455.9	2,738	1.88 : 1	1,788.8	2,324	1.30 : 1	1,862.4	2,724	1.46 : 1
142–1	1,174.4	2,232	1.90 : 1	1,251.2	2,438	1.95 : 1	......	.....	......
Early New Market P. B. 1569	1,155.2	2,546	2.20 : 1	1,433.6	2,092	1.46 : 1	1,718.4	2,462	1.43 : 1
Red Texas P. B. 1570	979.2	3,050	3.11 : 1	1,206.4	2,182	1.81 : 1	1,628.8	2,802	1.72 : 1

which equals 1.26. This means that 1.26 pounds of straw were required for each pound of grain produced. In this same manner the ratios for all the strains which were tested in the three years, 1911, 1912 and 1913 have been calculated. These ratios are given in Table 1.

The question naturally arises whether this ratio varies greatly from year to year or whether it is fairly constant for the same variety in the different years. If it is more or less constant then it may be used as a factor in selecting varieties. With this in mind the data for the ratio is arranged in Table 1 to throw some light on this question. In this table are given the yields of grain and straw as well as the ratios of grain to straw.

The table is arranged in the ascending order of the ratio of straw to grain for the 1911 results. That is, the strain having the lowest ratio in 1911 is placed first and the other strains are arranged in ascending order with respect to their ratios for that year. The yields and ratios are also given for each of the strains tested in 1912 and 1913. It is obvious that the ratios for 1912 and 1913 do not follow the exact order that they do in 1911. It is apparent from this table, however, that in general those strains which gave the lowest ratios for 1911 also produced the lowest in 1912 and 1913 and on the other hand the highest ratios in 1912 and 1913 came from those strains having a high ratio in 1911. By dividing the different strains and varieties tested in 1911 and 1912 into two equal lots and obtaining the average ratios for the two years the following results are obtained. The first 26 in 1911 had an average ratio of 1.25 while the same ones gave the same average in 1912. The second 26 in 1911 averaged 1.69 while the same strains in 1912 gave an average of 1.45 and the ones tested in 1913 from each lot gave an average of 1.22 and 1.48 respectively, showing a tendency to reproduce the ratio to some degree. In other words, the ratio of straw to grain seems fairly constant for the same strains in different years.

This is further illustrated by means of Fig. 10, which represents graphically the ratios obtained for the different strains for the two years 1911 and 1912. The solid line represents the ratios for the different strains for 1911 arranged in ascending order (according to the ratio) and the dash line represents the ratios for the same strains in 1912. The straight line XX which has been fitted to the dash line by the method of least squares shows a decided slope upward. The equation is $y = 1.14 + .0083$ thus showing that the ratio of 1912 follows the ratios of the same varieties for 1911.

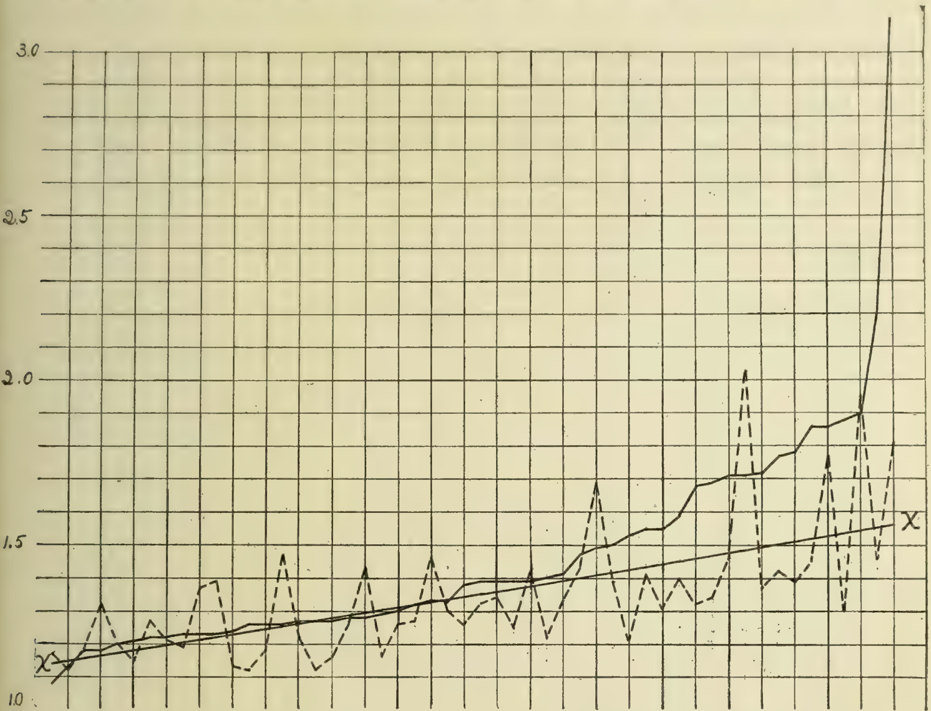


FIG. 10.—Ratio of straw to grain for oats tested in 1911 and 1912. Solid line 1911; broken line 1912; XX fitted straight line.

The data for those strains tested for the three years is shown graphically in Fig. 11. In this chart the ratios for 1911 are represented by the solid line and are plotted in ascending order. The ratios for the same varieties for the year 1912 are illustrated by the dash line and for 1913 by the dotted line. The straight lines XX and YY are fitted to the 1912 and 1913 data by the method of least squares. The equations for the two years are $y = 1.15 + .01$ and $y = 1.12 + .012$ respectively, thus showing a decided upward slope. The fact that these

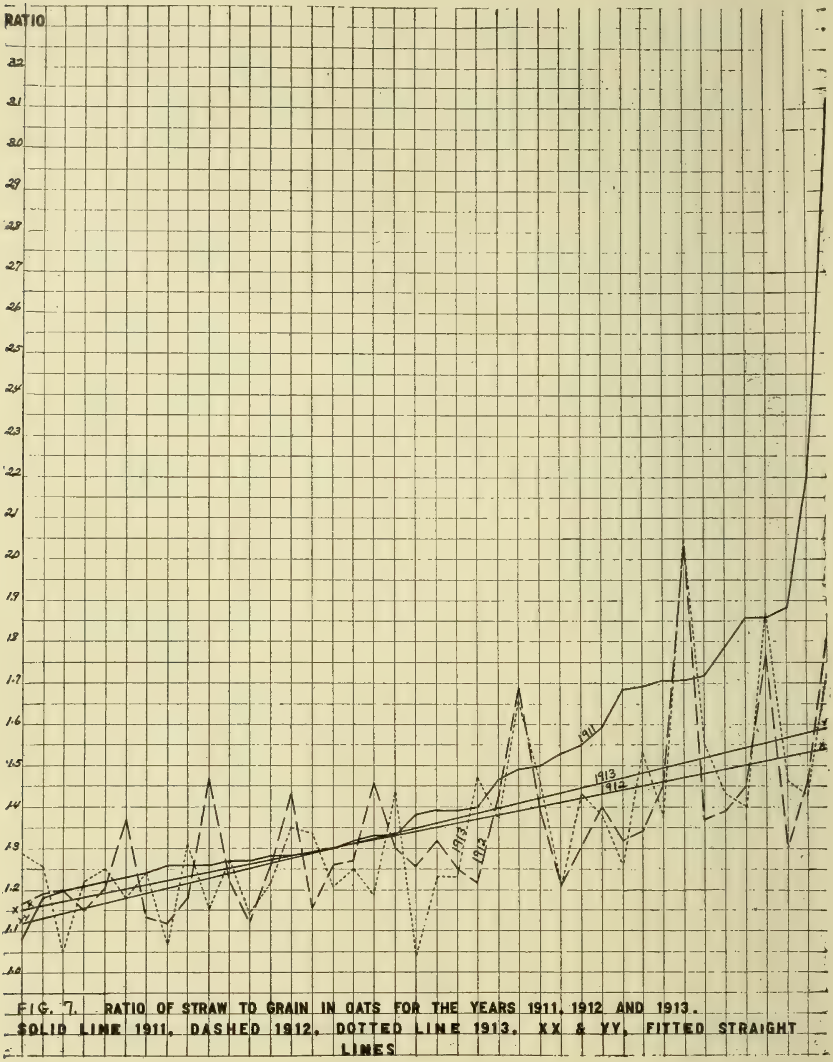


FIG. 11.—Ratio of straw to grain in oats for the years 1911, 1912 and 1913. Solid line 1911; dashed line 1912; dotted line 1913; XX and YY, fitted straight lines.

straight lines from both figures a decided upward slope indicated that there is a tendency for the ratio to be somewhat constant from year to year. This means that a definite amount of straw is required to produce a pound of grain each year and may be considered a varietal characteristic. There is a tendency for the ratio to be very low for certain varieties while in others it is very high. The average pounds of straw for the three years required to produce a pound of grain for the strains 50*a*1–10 and 34*a*1–11–12 is only 1.15 while, on the other hand, such varieties as Golden Giant Side, Black Tartarian and Red Rustproof require 1.93, 1.83 and 2.21 respectively.

It is interesting to compare the ratios of some of the commercial varieties and those of the selection obtained from these varieties. For example, the average ratio of the Welcome variety for the three years is 1.55, while that of 123–5, a selection from Welcome, is 1.20. This shows that a lower ratio has been obtained in the selection, or in other words, more grain per weight of straw. This is also brought out by the total weight of straw and grain for these two lots. The total weight of straw for the Welcome variety was 7,624 pounds, while the total weight for the selection was 7,804 pounds, which is only slightly more. When it comes to the question of grain for the three years, however, the Welcome variety produced 4,975.8 pounds while the selection produced 6,486.4 pounds, a gain of 47.2 bushels of grain although the straw yield is nearly the same. Other cases might be pointed out, but the one mentioned is of the most importance and serves to illustrate the point.

From this table it is apparent that the early strains of the Sixty Day or Burt types, or hybrids of these with other varieties, are, in general, low in yield of straw, while some of the Silvermine and Welcome selections produce greater yields of straw. Some of the standard varieties yield more straw in comparison with the grain than many of the new hybrids and selections given here.

The relation of yield of straw to the percentage of meat for the different varieties was determined and it was found that there was an important relationship between these two characters. The correlation between percentage of meat and yield of straw for the varieties grown in 1913 gave a correlation coefficient of –.621 ± .035, showing that as the yield of straw increased there was a decrease in percentage of meat. In other words, those strains producing heavy yields of straw produced kernels having a thick hull. This indicates that care should be exercised when selecting a variety for heavy yield of straw to see that it is as thin hulled as is possible.

The foregoing data show that there is a very close relationship between yield of grain and yield of straw for the different varieties and that this is fairly constant from year to year and is not merely an environmental relation. Certain exceptions occur, but on the whole, one may expect an increase in yield of grain with a corresponding increase in yield of straw. The ratio of straw to grain is also shown to be fairly constant from year to year. Certain strains produced almost a pound of grain for every pound of straw while others required nearly two pounds of straw to produce a pound of grain. While a heavy yield of straw was found to be correlated with a heavy yield of grain it was in turn correlated with a small amount of meat.

FIELD TESTS WITH A TOXIC SOIL CONSTITUENT: SALICYLIC ALDEHYDE.[1]

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Salicylic aldehyde has been isolated from an unproductive soil, and compounds of an aldehyde nature have been shown to exist in many soils.[2] Such soils are usually unproductive. When separated from soils, the aldehyde material is toxic to plants in pure water and in nutrient solutions. The isolated salicylic aldehyde is harmful in quite small amounts. Its toxicity has been demonstrated in distilled water cultures, in nutrient solutions and in soil in pots. The crops tested were wheat, corn, clover, cowpeas, cabbage, and rice, and all of them were injured or retarded in growth by this substance. The question remained whether this soil substance would prove harmful to plants under field conditions and whether it would subsist under field conditions long enough to influence crop yield. Field tests with such substances have so far not been feasible, because of the impossibility of securing enough material to make the tests, but in the case of salicylic aldehyde this obstacle has been overcome.

The effect of the salicylic aldehyde in soils under field conditions was tested on plots at the Arlington Farm, Virginia. Three crops, cowpeas, string beans and garden peas, were grown on the treated soil during the summer of 1913. Adjoining to each plot growing a different crop, two check plots of equal size were planted with that same crop. The area of each plot was one fourth of a square rod.

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[1] Received for publication June 3, 1914.

[2] Shorey, E. C., Some Organic Soil Constituents, U. S. Dept. Agr., Bureau of Soils, Bull. 88 (1913).

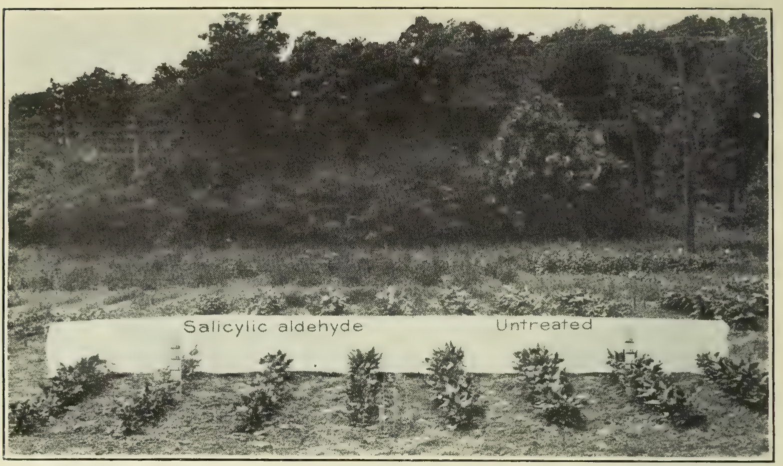

FIG. 1.—Effect of salicylic aldehyde on cowpeas in the field.

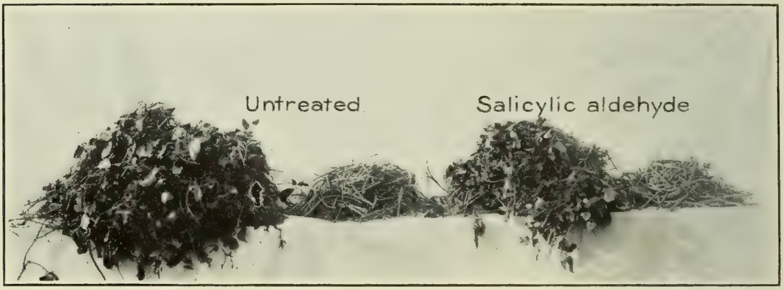

FIG. 2.—Yield of cowpeas, vine and pod, on check plot *b* and on salicylic aldehyde treated plot.

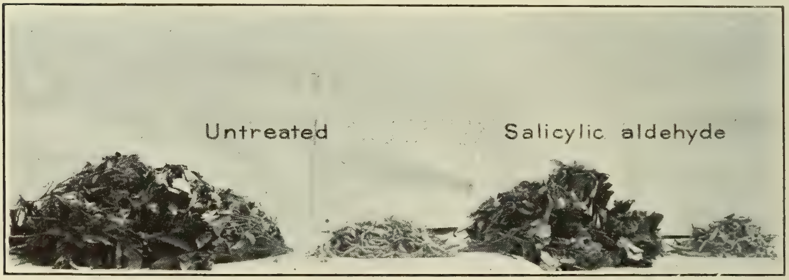

FIG. 3.—Yield of string bean, vine and pod, on check plot *b* and on the salicylic aldehyde treated plot.

The soil on which the experiment was made is a heavy silt clay loam, low in organic matter. The land was plowed early in May and prepared for the seeding with the above leguminous crops. Three applications of salicylic aldehyde were made, the first on May 20, one day before the crops were planted. The second application was made after the plants were up, on June 5; the third on June 24. Each application was at the rate of 35 lbs. per acre, or a total of 105 lbs. per acre.

The salicylic aldehyde was applied by dissolving in water and sprinkling the solution uniformly on the surface of the ground before planting and the soil raked thoroughly. After planting, the second and third applications were made by sprinkling the solution between the rows, and the soil then cultivated.

All of the three crops germinated uniformly. The untreated check plots made the better growth from the very start. The effect of the salicylic aldehyde was noticeable throughout the experiment. The crops were grown to maturity and harvested.

Effect on Cowpeas Grown in the Field

Both treated and untreated plots were sown to cowpeas on May 21, 1913, and the crop harvested on September 7, 1913. The cowpeas on the salicylic-aldehyde-treated plot were much stunted in growth. The appearance of the plants on June 27 is shown in Plate III, fig. 1. The four rows of plants on the left are growing on the treated plot. The four rows on the right are growing on an untreated plot. It is evident that the salicylic aldehyde is interfering with the proper development of the young plants. The effect became even more marked as the plants approached maturity. When mature, the peas were picked from the vines and weighed. After drying the peas were shelled and measured. The vines themselves were cut and their weight taken. After curing, the weight of the dry hay was recorded. In Plate III, fig. 2 are shown the vines and peas as gathered from the check plot and from the salicylic aldehyde-treated-plot. The effect of the salicylic aldehyde in depressing crop yield is apparent.

In Table 1 are given the results obtained in this experiment with salicylic aldehyde and cowpeas. The results are given as obtained from the individual plots and also in terms per acre.

From the table it will be seen that the yield of green cowpea vines was decreased 3.04 tons per acre by the salicylic aldehyde, a reduction of 35 percent in yield. The cured hay was reduced 53 percent in yield and the yield in pods was reduced 43 percent. The aver-

TABLE 1.—*Yield of Cowpeas as Affected by Salicylic Aldehyde in the Field.*

Treatment.	Yield per Plot.			Yield per Acre.		
	Vines.		Pods.	Vines.		Pods.
	Green.	Cured.		Green.	Cured.	
	Pounds	*Pounds*	*Pounds*	*Tons*	*Tons*	*Tons*
Check *a*.	28.0	10.0	6.6	8.96	3.20	2.11
Check *b*.	23.0	8.5	5.6	7.36	2.72	1.79
Average check.	25.5	9.3	6.1	8.16	2.96	1.95
Salicylic aldehyde. . . .	16.0	4.3	3.5	5.12	1.38	1.12
Difference.	9.5	5.0	2.6	3.04	1.58	0.83

age yield of green vines and pods on the check plots was 10.11 tons, and on the salicylic aldehyde plot, it was only 6.24 tons, making a total decrease of crop, 3.87 tons or 38 percent.

EFFECT ON STRING BEANS IN THE FIELD.

The string beans were less affected by the salicylic aldehyde than the cowpeas and also less than the garden peas. The seed was sown May 21, this germinated well, and a good stand was secured. As the crop grew it became apparent that there was a difference in the growth of the treated plots and the untreated, but it was not as marked as with the cowpeas. On July 22 the crop was harvested and the weight of green vine and beans obtained separately. The results are given in Table 2 and a photograph of the harvested crop is shown in Plate III, fig. 3.

TABLE 2.—*Yield of String Beans as Affected by Salicylic Aldehyde in the Field.*

Treatment.	Yield per Plot.			Yield per Acre.		
	Vines.	Beans.		Vines.	Beans.	
	Pounds	*Pounds*	*Pints*	*Pounds*	*Pounds*	*Pecks*
Check *a*.	3.55	1.90	4.75	2272	1236	190
Check *b*.	2.94	1.66	4.15	1882	1062	166
Average check.	3.24	1.78	4.45	2070	1149	178
Salicylic aldehyde. . . .	2.71	1.25	3.12	1734	800	125
Difference.	.53	.53	1.33	336	349	53

The average yield of vines and beans on the check plots was 3,219 lbs. per acre and on the salicylic aldehyde plot it was only 2,534 lbs., a decrease of 685 lbs. of green matter per acre.

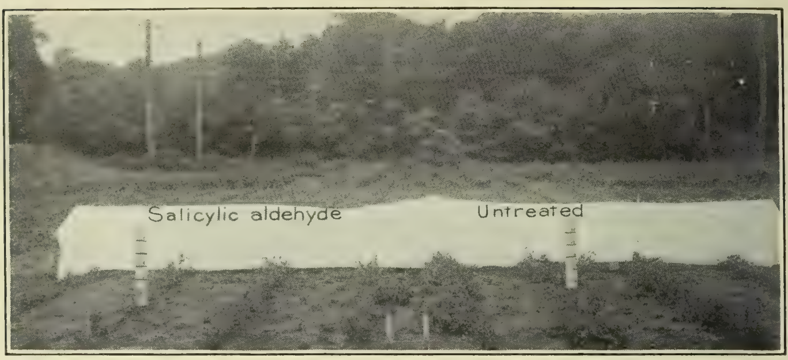

FIG. 1.—Effect of salicylic aldehyde on garden peas in the field.

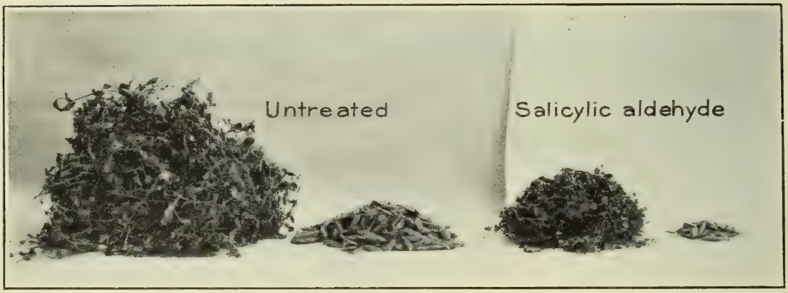

FIG. 2.—Yield of garden peas, vine and pod, on check plot *b* and on the salicylic aldehyde treated plot.

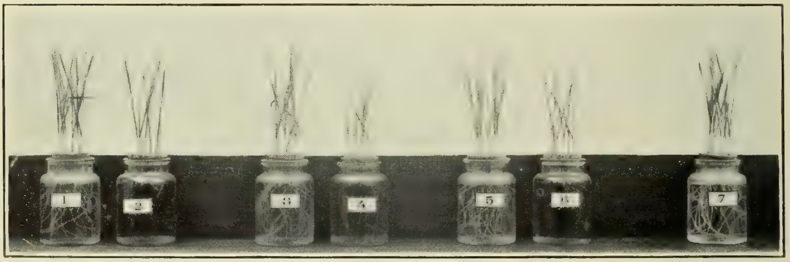

FIG. 3.—Effect on wheat of extract from Arlington soil six months after field application of salicylic aldehyde: (1) distilled water containing substance extracted from untreated cowpea plot; (2) from treated cowpea plot; (3) from untreated garden pea plot; (4) from treated garden pea plot; (5) from untreated bean plot; (6) from treated bean plot; (7) control in distilled water.

The yield of marketable bean crop was reduced 53 pecks per acre, or 30 percent.

EFFECT ON GARDEN PEAS IN THE FIELD.

The garden peas were sown on May 21 and a good stand was obtained. The plants showed from the start the effect of the salicylic aldehyde and this became more pronounced with the other additions and as it neared maturity. The matured vines and pods were harvested separately on June 30 and weighed. Fruit formation was practically nothing on the salicylic aldehyde treated plot. The appearance of the treated and untreated plots on June 24 is shown in Plate IV, fig. 1. The harvested crops are shown in Plate IV, fig. 2. The weights and measurements obtained are given in Table 3.

TABLE 3.—*Yield of Garden Peas as Affected by Salicylic Aldehyde in the Field.*

Treatment.	Yield per Plot.			Yield per Acre.		
	Vines.	Peas.		Vines.	Peas.	
	Pounds	*Pounds*	*Pints*	*Pounds*	*Pounds*	*Pecks*
Check *a*............	1.72	1.66	4.50	1101	1062	180
Check *b*............	1.50	1.48	4.00	950	947	160
Average check.......	1.61	1.57	4.25	1030	1004	170
Salicylic aldehyde....	.52	.16	.43	333	102	17
Difference..........	1.09	1.41	3.82	693	902	153

The photograph and the table show conclusively the extremely harmful action of the salicylic aldehyde on garden peas. The yield of total plant material, vines and pods was 2,034 lbs. per acre as an average of the untreated checks, as compared with 435 lbs. on the salicylic aldehyde plot, a decrease of 1,599 lbs. The marketable crop, that is the peas in shell, was depressed from 1,004 lbs. to only 102, or 90 percent, practically a total failure.

EXAMINATION OF THE FIELD PLOTS FOR ALDEHYDE SIX MONTHS AFTER APPLICATION

That salicylic aldehyde can persist in some soils would seem to be indicated by the facts given in the papers cited.

In order to further verify this ability of the aldehyde to persist in some soils the salicylic-aldehyde-treated field plots were subjected to an examination for aldehyde. Soil samples were collected from the cowpea plots, the string bean plots, and the garden pea plot; i. e., a sample from each check plot and each salicylic aldehyde plot.

These six samples were examined for aldehyde. The three check samples contained none, the three treated plots showed the presence of aldehyde. The residues obtained in this procedure for separating aldehydes were tested with wheat seedlings just as described in the paper earlier. The extract from the check plots, which showed no aldehyde, grew plants as well as pure distilled water, whereas the exextracted material from the aldehyde-treated plots showed itself to be harmful to the wheat seedlings. The extract from the treated cowpea plot decreased growth 32 percent; that from the string bean plot decreased growth 27 percent; that from the garden pea plot decreased growth 26 percent. The harmful effect of the aldehyde material, extracted from the treated plots, is shown in Plate IV, fig. 3.

The existence of the harmful compound in the soil was also shown in another way by growing wheat in the greenhouse in the paraffined wire pots, using the respective soils from the salicylic-aldehyde-treated plots and the check plots. The table shows that the soils from the salicylic-aldehyde-treated plots are harmful to wheat in soil collected six months after the salicylic aldehyde was applied. The results of this experiment are given in Table 4. Two pots, with six plants each, were used for each soil. The plants grew from December 11 to January 6.

Table 4.—*Growth of Wheat in Pots of Soil Taken from the Field Plots Six Months after Treatment with Salicylic Aldehyde.*

	Wheat on Soil from Plots Untreated.	Wheat on Soil from Salicylic Aldehyde Plots.	Relative Growth. Check = 100.
	Grams	*Grams*	*Grams*
Cowpea plot..........	1.48	1.18	80
String bean plot.......	1.54	1.11	72
Garden pea plot.......	1.47	1.22	83

A similar experiment was made with these soils except that the crops grown in the pots were identical with those which had grown in the field the preceding season, that is, cowpeas on the cowpea soil from the check plot and from the salicylic aldehyde plot, string beans on the string bean soil from both check and treated plot, garden peas on the garden pea soil from both check and treated plot. Two pots were used in each case and two plants in each pot. The plants grew from December 11 to January 6. The vegetative growth made in this experiment is given in Table 5.

The table shows that the salicylic-aldehyde-treated soil was still harmful to the respective crops seven months after the application of

TABLE 5.—*Growth of Cowpea in Pots of Soil from the Cowpea Field Plots; String Bean in Soil from the Spring Bean Field Plots; Garden Pea in the Soil from the Garden Pea Field Plots; Collected Six Months After Treatment with Salicylic Aldehyde.*

Crop Grown in Pots in Greenhouse and Previously in the Field.	Soil from Plots Untreated.	Soil from Salicylic Aldehyde Plots.	Relative Growth Check = 100.
	Grams	*Grams*	*Grams*
Cowpea	4.30	3.80	88
String bean	7.80	7.20	92
Garden pea	5.60	4.30	77

the salicylic aldehyde and about five months after the harvesting of the same crop in the field. It is also interesting to note that the relative order of toxicity shown toward the different crops is the same in these smaller vegetative experiments in the paraffined wire pots as was found to be the case where the crops were harvested in the field. This would also seem to indicate that the observed order of toxicity toward these plants, namely, garden pea, cowpea, string bean, may be more than accidental.

MOISTURE AS A FACTOR OF ERROR IN DETERMINING FORAGE YIELDS.

ROLAND MCKEE. (INTRODUCTION BY C. V. PIPER).

OFFICE OF FORAGE CROP INVESTIGATIONS, U. S. DEPARTMENT OF AGRICULTURE.

The article entitled "Basing Alfalfa Yields on Green Weight," by Mr. F. D. Farrell, in Vol. 6, pp. 42–45, of this JOURNAL has suggested the advisability of presenting at this time unpublished data of some earlier work along the same line, which throws additional light on the practicability of using the green weight or perhaps the weight of field-cured material corrected by sample, as the basis for yield data in forage crop investigations. This work was begun at Chico, California, in 1910 and continued during the succeeding years as preliminary to a more extensive series of investigations now being conducted. Some of the results were published in B. P. I. Circular 119–D, entitled "Arabian Alfalfa."

At the Tennessee Experiment Station forage yields have for the past ten years been corrected by taking a sample of the green material as it was weighed and then determining the loss of moisture in this sample after allowing it to become perfectly air-dry. It was thus possible to bring the forage yields to a standard percentage of moisture, at least as far as the accuracy in sampling would permit.

It is questionable whether it is better to take samples from the perfectly green material or from the field cured or partially cured material as it is weighed on the plots. The green sample is apt to be more uniform than the sample taken from partially cured material unless extreme care is used with the latter. The results at Chico, California, show that once a crop has been cut with a mower and exposed to bright sunlight it loses moisture very rapidly. Therefore, unless sufficient care is used so that each plot is subjected to the same amount of exposure before the green weight is taken or in lieu of this that a sample is taken from each plot at the exact time when the total green weight is determined the error may be larger than that arising from the non-uniformity of samples taken from partially cured material. A glance at tables 2 and 4 in the accompanying article by Mr. McKee will show that alfalfa exposed to bright sunlight loses practically 25 percent of its moisture during the first hour after cutting. It appears therefore that a difference of only 15 minutes between the elapsed time of taking the green weights and the sample might mean an error of 6 percent.

This work of Mr. McKee with alfalfa at Chico shows a somewhat lower final moisture percentage than did that reported by Mr. Farrell, the moisture loss being from 78 to 80 percent. This difference is probably due chiefly to the longer elapsed time from cutting until the final weighing, but perhaps also to lower atmospheric humidity. Whether the correction of field-cured weights by sample is more practicable than taking green weights and reducing these by a certain percentage of moisture loss to an air-dry basis is yet open to question. It is hoped that this description of the first-named method may be useful and that the results presented will be of interest in determining the most satisfactory method for securing accurate weights in forage experiments.

* * *

In experimental work in determining forage yields, either with varieties in comparison or with a single variety or crop, it is quite desirable, if not essential, that the weights be taken in such a way that it is possible to interpret them, except in the case of succulents, on the basis of water-free substance, or on that of air-dry matter.

It is generally admitted that forage yields should be expressed in comparable terms and most experimenters express such data on what is intended, or assumed, to be an air-dry basis. Few experimenters, however, give due consideration to the handling of the crop after cutting in its relation to the possible error from moisture content that may enter into such yields.

In connection with experiments on the comparative hay yields of alfalfa varieties, it has been clearly determined that the difference in the rate of moisture loss in the different varieties immediately after cutting varies sufficiently so that even in good drying weather weights taken any time within two days may not be truly comparable. After sufficient time, however, the moisture content of the different varieties becomes the same, or so nearly uniform that the error is very slight.

This phenomenon of varieties losing moisture at different rates after cutting is of much importance in securing comparative yields and must be given due consideration when weights are taken in the field within a few days after cutting, as is commonly done.

Data as to the rate of loss of moisture in alfalfa varieties at Chico, California, are given in the following tables.

TABLE 1.—*Showing Rate of Loss of Moisture in Alfalfa Varieties After Cutting, at Chico, California, in 1910. Plants in First Bloom.*

Variety.	Green Weight.	Percentage Moisture Lost in 24 Hrs.	Percentage Moisture Lost in 72 Hrs.
	grams	*percent*	*percent*
Arabian	254*	61.14	69.82
Peruvian	276*	52.96	66.78
Ordinary	240*	55.23	65.31

* Sample weighed about 5 minutes after cutting.

TABLE 2.—*Showing Rate of Loss of Moisture in Alfalfa Varieties After Cutting, at Chico, California, in 1911. Plants in First Bloom.*

S.P.I. No.	Variety.	June 9.				Weight Sept. 27.	Percentage of Original Weight Sept. 27.	Percentage by Weight Leaves.
		Weight 10:22 A. M.*	Weight 11:52 A. M.	Weight 1:22 P. M.	Weight 4:00 P. M.			
		grams	*grams*	*grams*	*grams*	*grams*	*percent*	*percent*
24367	Arabian	400	246	176	144.3	84.7	21.2	58.9
24367	Arabian	400	241.5	172.5	145.8	82.5	20.6	53.9
22948	Peruvian	400	279	221	181.7	86.4	21.6	50.6
22948	Peruvian	400	263.5	203.5	164.0	80.1	20.0	54.4
21829	Ordinary	400	273.5	211.5	177.3	80.3	20.0	52.6
21829	Ordinary	400	265	200	174.4	84.7	21.1	47.0

* First weight was taken *immediately* after cutting.

In Tables 2 and 3 it is shown that when air dried, alfalfa is a little more than 20 percent of its green weight, and in Table 5 it is shown

TABLE 3.—*Showing Rate of Loss of Moisture in Alfalfa Varieties after Cutting, at Chico, California, in 1911. Plants in First Bloom.*

S. P. I. No.	Variety.	Weight Perfectly Green 9:07 A. M. June 9, 1911.	Weight 11:00 A. M. June 9, 1911.	Weight* 2 P. M. June 9.	Weight 4 P. M. June 9.	Weight June 12.	Weight August 8.
		pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
24367	Arabian	100	73	41	36	24	22
23467	Peruvian	100	78	48	42	24	22

* Bunched 2 P. M.

that alfalfa reduced to a water-free basis is a little more than 14 percent of its green weight.

TABLE 4.—*Showing Rate of Loss of Moisture in Alfalfa Varieties after Cutting, at Chico, California, in 1912. Plants in First Bloom.*

Variety.	Weight 10:00 A. M.	Weight 11:00 A. M.	Weight 12:00 M.	Weight 2 P. M.	Weight 4 P. M.
	pounds	*pounds*	*pounds*	*pounds*	*pounds*
Arabian	100	78.5	60.5	34.5	26
Peruvian	100	83.5	65.5	31.5	24.5

Various published determinations state that field-cured alfalfa hay as ordinarily handled by farmers contains from 12 to 30 percent of moisture.

TABLE 5.—*Showing Amount of Moisture in Green Alfalfa at Chico, California, in 1911.*

S. P. I. No.	Variety.	Moisture Average of Four Samples.	Dry Matter.	Remarks.
		percent	*percent*	
24367	Arabian	86.0	14	Not quite in bloom.
24367	Arabian	85.2	14.8	Few plants in bloom.
22948	Peruvian	86.0	14	Few plants in bloom.
23467	Peruvian	85.5	14.5	Not quite in bloom.
21829	Utah	86.7	13.3	Not quite in bloom.
13520	Selection	86	14	Not quite in bloom.
19969	Selection	85.2	14.8	Not quite in bloom.
Average of all varieties . . .		85.8	14.2	

The tables, aside from showing that different varieties lose their moisture at different rates, also show that the loss in any variety is very rapid immediately after cutting and that in making comparisons of yields by green weights the forage must be handled very promptly after cutting and the time between cutting and weighing in varieties or plots being compared must be the same or the error due to the different quantities of moisture lost will invalidate the data. In Table 4 it will be noted that 21.5 percent of the total green weight of the Arabian variety was lost as moisture in one hour, and 16.5 percent of the total green weight of the Peruvian variety was lost in the same time. Tables 2 and 3 show similar results.

In weighing forage directly from the field, at the time it is considered ready for the stack or mow, the weights will seldom truly represent air-dry weights. The moisture contents of different varieties or plots at time of weighing will usually vary considerable even when the weights are taken by one person. Different experimenters weighing forage directly from the field without making exact determination of the moisture content can not secure truly comparable data.

In order that forage yield data may be of the greatest value care should be taken in handling the different varieties and plots compared so that error from variation in moisture content may be eliminated or reduced to a minimum. To make forage yield data of the greatest value they should be determined on the basis of both water-free substance and air-dry matter. However, it is not always convenient to make water-free determinations, but weights can very easily be corrected to an air-dry basis.

To do this, before making weighings the forage should be allowed to dry as much as is practicable. The total weight should then be determined and a representative sample of the forage taken for the purpose of correcting the moisture content to an air-dry basis. This sample should be large, two pounds or larger if the forage is rather green, and should be weighed immediately. After weighing, these samples should be exposed to the air and allowed to come to a uniform air-dry basis when they should be again weighed and the percentage of loss of moisture determined to be used in correcting the original weights of the plots or varieties from which they were taken. The time the samples will take to reach an air-dry basis will vary with climatic conditions and with different crops. In most cases ten days should elapse, and several air-dry weights should be taken at successive dates. When two weighings are made the one serves as a check on the other. When a two-pound sample is used the weights should be taken in as fine a division as grams. By following the foregoing suggestions in regard to correction of the air-dry weights, it is believed that data relative to forage yields can be made more accurate than those now found in publications.

NOTES ON OATS FOR THE SOUTHERN STATES.

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In the February Journal of Heredity there appeared a very interesting article on "The Origin of Cultivated Oats" by Dr. L. Trabut, director of the botanical service of the Government of Algeria. This paper was originally presented by Dr. Trabut at the Fourth Congress of Genetics in Paris in 1911. It does not discuss in detail the origin of all varieties of cultivated oats, but only of those which are commonly grown in the Mediterranean region of southern Europe and northern Africa. The usually accepted theory that *Avena fatua* is the parent of the varieties of oats grown in the north of Europe is accepted by Dr. Trabut, but he brings forward quite convincing evidence to show that the cultivated oats of the Mediterranean region have been produced from *A. sterilis,* a wild form which is still common there. The character on which the separation between derivatives from *A. fatua* and *A. sterilis* is made is the method of disarticulation of the second kernel in the spikelet. In *A. fatua* and varieties produced from it, the rachilla breaks off at the base of the second kernel and remains attached to the inner face of the primary one. On the other hand, in *A. sterilis* and its derivatives, the second kernel carries its rachilla with it when disarticulated. Dr. Trabut describes and illustrates a very interesting series showing the transition from the wild to the best cultivated forms. The paper is of much value to botanists and agronomists in that it adds to the general knowledge of the origin of our cultivated plants and emphasizes the fact that certain varieties of oats are particularly adapted to warm climates because they have been derived from a wild species which is native to a subtropical region.

The theory that all our cultivated varieties of oats have not been derived from *Avena fatua,* but that certain forms adapted to warm climates have been developed from *A. sterilis,* is not, however, entirely new. In a paper presented before the third annual meeting of the American Breeders' Association Mr. J. B. Norton[1] makes the following statements:

> "It has been generally accepted that *Avena fatua,* the common wild oat of Europe and Asia, is the progenitor of all our cultivated forms. Such, how-

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[1] Norton, J. B., Notes on breeding oats, Proceedings, American Breeders' Association, 3: 280–285, 1907.

> ever, is not the case. The red oats of the South and some related forms are undoubtedly descended from *Avena sterilis* of the Mediterranean region."

Mr. Norton then points out certain resemblances between *sterilis* and the varieties of oats commonly cultivated in our Southern States. This opinion with regard to the diverse origin of the oats commonly grown in the south and in the north has also been held by certain others who have studied this crop.

In discussing the value of derivatives of *A. sterilis* in breeding, Dr. Trabut observes:

> "We have yet to determine in what degree a true hybridization will be possible. If *Avena fatua sativa* may be crossed with *Avena sterilis culta* a progeny may be produced having very useful mixed characters."

Mr. Norton's statement that "Hybrids between *Avena fatua* derivatives and *Avena sterilis* derivatives show many interesting reversions to the wild forms in the second generation" shows that such hybrids have been made. As a matter of fact Mr. Norton made a considerable number of hybrids between varieties belonging to the *Avena fatua sativa* of Trabut and cultivated forms of *A. sterilis,* particularly one from Asia Minor, which he called "Asia Minor Rustproof." From some of these hybrids, particularly from the one in which the *A. sativa* variety Danish Island, a medium late white oat, was the female parent, some valuable selections have been obtained. Unfortunately no Mendelian studies were made of these hybrids, so that there are no data on the dominance of such characters as the method of disarticulation of the second flower. In the selections which have been preserved, both methods described by Dr. Trabut are to be found.

While Dr. Trabut's article itself is to be highly commended, the editorial introduction contains several statements which are evidently based on only a slight knowledge of oat varieties and oat culture in the southern United States. The most striking observations in this introductory statement are as follows:

> "The prevailing belief that oats can not be grown in the southern United States is probably based on the fact that all the experiments made there have been with cold-climate oats. A great deal of money has already been lost by such attempts, foredoomed to failure because of unsuitableness of the material:—although suitable material might have been had, and the country's wealth thus enormously increased had growers studied the genetic history of the cultivated oats earlier."

To those who are familiar with southern agriculture, this statement of a "prevailing belief" will doubtless come as a surprise. While it is true that the oat crop is less important in the South than in the North, the annual area sown to oats in the Southern States for the decade ending in 1910 was nearly 3,500,000 acres. The estimated acre yield for the same period, however, is only about 75 percent of that for the entire United States, being a little less than 22 bushels as compared with 29.5 bushels for the entire country.

This low average yield is not in itself an argument that oats are not adapted to the South or that the varieties are not suitable. One might as well argue that corn is better suited to New England than to the South, because the average acre yields of corn are higher in New England. Yields of 70 to 100 bushels of oats to the acre, in the South, which are not unusual when the crop is properly grown on suitable soils, go far to show that soil and cultural conditions have much influence on the average results. The principal reasons for the low yields of oats commonly obtained in the southern United States are: (1) sowing on soils lacking in fertility; (2) poor preparation of the seed bed; (3) sowing too late in the fall; (4) sowing broadcast instead of drilling; and (5) sowing in late winter or spring instead of in the fall.

As compared with an average annual area of 3,500,000 acres in oats in the South during the ten years from 1901 to 1910, the estimated area in the same states in 1912 was over 4,000,000 acres and that in 1913 was 4,660,000 acres. A part of this increase is due to the settlement and development of Oklahoma during recent years, with the result that the acreage in oats and other crops is now much greater than in the earlier years of the decade ending in 1910, but there is also a very marked increase in the acreage devoted to oats in the Carolinas and the Gulf States. This rapid increase in acreage is hardly an indication of an unprofitable industry.

The most remarkable portion of the editorial statement, however, is that "all the experiments made there have been with cold-climate oats." The oat most commonly grown in the South is the Red Rustproof, which with the varieties derived from it, such as Appler, Lawson, Hundred-Bushel, Cook, and Bancroft, is probably sown on at least three-fourths of the area devoted to oats in the South Atlantic and Gulf States. The Red Rustproof has been grown for many years in the South and its origin is not now known, but a very casual examination will convince any one that it is quite distinct from "cold-climate" oats, and that, as stated by Mr. Norton several years ago, it belongs to the *A. sterilis* group.

The native Algerian oat discussed by Dr. Trabut has been grown side by side with the Red Rustproof and other varieties at a number of southern experiment stations, but has usually been discarded as inferior in yield and more particularly in winter hardiness. A considerable number of cultivated forms of *A. sterilis* from the Mediterranean region—Spain, Italy, European Turkey, Asiatic Turkey, and northern Africa—have also been grown on the Arlington Experiment Farm near Washington, D. C. Two essential characters of varieties of oats for the South are early maturity and adaptability to fall seeding. Although derived from *A. sterilis,* these varieties are all less valuable for our Southern States than Red Rustproof because they are later in maturing and less winter-hardy. Most of them, however, contain widely varying forms and some promising pure lines have been selected. Time alone will show whether they are superior to pure-line selections from the Red Rustproof, a form of *A. sterilis* which has had many years to adapt itself to our conditions.

In view of the fact that we have for many years been growing in the South what appear to be, from Dr. Trabut's article and from experiments, the most suitable varieties of oats, it is difficult to see just how "a great deal of money has been lost" or that the efforts to grow oats there were "foredoomed to failure." Figuring monetary gains or losses from the substitution or failure to substitute certain varieties for those commonly grown is no doubt a pleasant pastime, but it is well to have some definite information regarding the varieties in question before presenting the figures to the public.

BRIEFER ARTICLES.

THE USE AND MANAGEMENT OF CHECK PLATS IN SOIL FERTILITY INVESTIGATIONS.[1]

The principal object of this paper is to open a discussion of the methods employed in the management of check plats in field plat soil fertility investigations and whether or not their management could be modified to advantage. It is the hope of the writer that such a discussion, viewing the subject from all angles, considering the objects in using check plats, and studying the results that have been secured in some of the older experiment fields, will shed some light upon the question as to whether or not the practice of the past has been the correct one.

An examination of the older experiment fields reveals the fact that there is no uniformity in the proportion of check plats used. Some series have only one check, some have several unevenly distributed, while a few have every third plat a check. So far as I have been able to learn it has been the common practice to leave the check plats without any treatment in the way of fertilization.

In recent years the most common system in laying out a series of field plats has been to have an untreated check every third plat in the series. For example, in a 16-plat series plats 1, 4, 7, 10, 13 and 16 would be untreated checks. These check plats are intended not only to show what the land will produce without fertilization, but also to measure the progressive variation in the natural fertility of the land upon which the series of plats is located, and to serve as a means of making corrections for natural variations in the fertility of the differently treated plats in the series in determining the effect upon soil productiveness that may be properly attributed to the particular treatment applied. In making such corrections, it is commonly assumed that the difference in fertility between any two check plats is uniformly progressive; that is, if plat No. 4 yields 20 bushels of wheat and plat No. 7 yields 23 bushels then, if similarly untreated, plat No. 5 would yield 21 bushels and plat No. 6 would yield 22 bushels. This assumption is probably not strictly correct in the majority of instances and it may even lead to serious errors, and especially when the variations between checks are considerable. That the variations may be very irregular from year to year has been observed repeatedly by the writer and it has seemed evident that no conclusions could be safely based upon the results of a single season. Notwithstanding this, the check plat is the only means through which it is possible to at all accurately compare widely separated plats receiving different treatments. Since it seems fair to assume that seasonal variations will become more or less accurately balanced in the course of time, it seems probable that the best use that can be made of check plats in correcting for ununiformity of soil is to take the average total produce of each check plat during the progress of the experiment and construct a curve showing the differences. Then, assuming that the difference between any two points in the curve is uniformly progressive, calculate the probable check yield for each of the intervening plats. Then add to or subtract from the average yield of the actual check plats of the series the percentage increase or decrease produced on each treated plat as compared with its calculated probable check yield. Without going into this question in detail it might be mentioned in passing that it would be well to spend more time than is usually spent in preliminary cropping to test the relative fertility of adjoining plats under uniform conditions before different treatments are begun, thus getting a more accurate idea of the real variations in natural fertility at the beginning.

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[1] Prepared for but not presented at the special meeting held at Dallas, Texas, February 18, 1914.

Under the "no treatment" system of managing check plats, which seems to be most generally practiced, these plats become poorer and poorer from year to year until finally a dead level of minimum productiveness is reached. In other words, we must eventually reach the point where there will be no further diminution in the amount of plant food which will annually become available in the soil. As the soil becomes poorer through the constant removal of all the produce its store of available plant food is not only reduced, but its physical condition becomes worse and worse and crops become more and more subject to unfavorable climatic factors, plant diseases and insect injuries. The plat that is poorest in the beginning naturally first reaches the point of minimum productiveness. The other plats continue to go down hill for some time longer and it therefore follows that differences become less and less. For instance, one check plat may have a greater initial supply of organic matter than another, but this is eventually used up and during the process the initial difference in productiveness becomes less and less, thus disturbing the factor of progressive difference in the relative natural fertility of the intervening fertilized plats. Such a changing relation between the check plats has been observed by the writer on the older series of plats on the

Indiana Experiment Station field which were laid out in 1889 with every third plat an untreated check.

If the above mentioned conditions prevail, and the observations of the writer have led him to believe they do to a greater or less extent, then would it not be wise to try to maintain the check plats in a better condition of fertility by means of some rational manurial treatment calculated to return, in a measure at least, what has been removed from the plats? If the answer is yes, then it seems to me the desired object might be fairly satisfactorily attained by applying a standard manurial treatment to all the check plats on a particular crop once during each rotation. This might be either a standard commercial fertilizer of a certain amount or an application of uniformly prepared stable manure equal to some fixed proportion of the total amount of crop removed during the previous rotation. Whether this manurial treatment of the checks should be uniform for all and based upon the average production during the previous rotation, or calculated for each plat separately, according to what it alone has produced during the previous rotation, is a question which I have not been able to settle to my own satisfaction. On two of our most recently started experiment fields in Indiana where we are using a corn, wheat, clover rotation we have adopted the plan of treating the check plats all alike with a uniform dressing of carefully mixed stable manure equal to the amount which could be made from the average yield of corn and roughage produced on the check plats during the previous rotation. This dressing of manure is plowed under for the corn and the amount applied is calculated upon the basis of 1,200 pounds of manure per 1,000 pounds of produce.

It is hoped by the writer that this discussion of the use and management of check plats and the questions raised will be taken up by other members of this society and further analyzed with a view to arriving at the fullest solution of the problems involved.—A. T. WIANCKO, Purdue University, LaFayette, Indiana.

THE EFFECT OF RATE OF SEEDING ON COMPETITION IN WHEAT VARIETIES.

To what extent different varieties of wheat are affected by the competition due to various rates of seeding has never been fully determined. However, it has been shown that varieties differ from one another in their tillering habit when sown under like conditions of space and fertilization. This would seem to indicate that certain

TABLE 1.—*Influence of Rate of Seeding upon Certain Characters in Varieties of Wheat.*

	Rate of Seeding.	Average Length of Culm, In.	Average Length of Spike, Cm.	Total Weight of Grain, Grams.	Size of Grain.	Average No. of Culms per Plant.
Bearded Varieties:						
Deitz	1	39	5.06	17.1	130	3.27
	2	39	4.62	14.2	158	1.66
	3	36	4.40	11.6	125	1.10
Rudy	1	40	5.52	14.5	138	3.65
	2	39	4.80	11.4	131	1.83
	3	36	3.62	7.6	140	1.06
Swamp	1	39	5.16	13.0	122	3.62
	2	36	4.81	11.4	146	1.81
	3	36	4.41	10.2	140	1.21
Farmers' Friend	1	37	6.74	14.8	145	2.75
	2	38	5.02	12.3	139	1.67
	3	35	3.92	9.5	132	1.04
Auburn Red	1	43	5.83	17.7	135	3.14
	2	40	5.32	13.5	178	1.61
	3	38	3.80	9.1	147	1.06
Average	1	39.6	5.66	15.4	134	3.28
	2	38.2	4.91	12.5	150	1.71
	3	36.2	4.03	9.6	136	1.09
Beardless Varieties:						
Red Wave	1	40	5.58	16.1	163	2.20
	2	34	4.49	9.6	177	1.09
	3	34	2.90	5.2	160	1.04
Early Red Clawson	1	37	5.30	14.0	160	2.41
	2	36	4.80	9.7	145	1.22
	3	36	4.10	5.2	162	1.02
Dawson's Golden Chaff	1	36	4.46	13.6	163	2.75
	2	32	4.00	7.8	168	1.19
	3	31	2.35	3.4	205	1.03
Currell's Prolific	1	36	4.76	10.3	174	2.23
	2	32	4.06	6.3	204	1.28
	3	32	2.96	3.9	205	1.04
Fultzo-Mediterranean	1	39	5.62	12.4	164	2.89
	2	37	5.10	10.0	196	1.51
	3	34	2.76	3.3	215	1.17
Average	1	37.6	5.04	13.2	164	2.49
	2	34.2	4.49	8.6	178	1.25
	3	33.4	3.01	4.2	189	1.06

varieties of wheat might withstand more liberal seeding than others. Previous studies[1] along this line show that some varieties are apparently able to utilize the plant food applied to much better advantage than others. In other words there seem to be among varieties of wheat sorts that are relatively "strong feeders." Noting these differences the writer proceeded to test several of the standard varieties of wheat with the view of determining how various rates of seeding affect the wheat plant, particularly the length of spike and yield of grain.

In the fall of 1912 a large number of varieties of wheat were sown at three different rates. In order to get the same number of kernels on a given space the grains were counted. For the first ten feet of row, 100 kernels were planted, the next ten feet 200, and the third ten feet 400 kernels. The next variety was sown in a similar manner just eight inches from the other so that when finished the varieties were eight inches apart in drill rows, practically the same as under field conditions. When the seedling plants appeared the number was noted for each variety under the different rates of seeding. At harvest time the number of culms from each rate of seeding was determined. Twenty-five average spikes from each rate of seeding of each variety were selected, measured and the grain carefully threshed by hand. The total number of culms arising from each rate of seeding was divided by the number of seedlings and the average number of culms per plant found. Thus the average length of culm and spike, the number of culms per plant and the total yield of grain from 25 spikes were secured from the different rates of seeding. The relative size of grain was determined by counting the number of grains in five grams.

Table 1 shows the data for ten of the standard varieties of wheat:

For comparison the ten varieties are divided into two classes, bearded and beardless. The numbers, 1, 2, 3 refer to the different rates of seeding respectively, thin, medium and thick. The final averages are taken for the different characters under the three rates of seeding for the bearded varieties as a lot, and in the same way for the beardless.

A comparison of the length of culms under the different rates of seeding shows that the bearded varieties have dropped from an average length of 39.6 inches under thin seeding to 36.2 inches under thick seeding, a difference of 3.4 inches, or 8 percent shorter culms under thick seeding. The beardless varieties averaged 37.6 inches in length under thin seeding and fell to 33.4 inches under thick seeding, a difference of 4.2 inches or 11 percent shorter straw under thick seeding. The variety Early Red Clawson is a notable exception to the general behavior of beardless varieties under thick seeding, as the length of culm was only one inch less under thick seeding. The bearded varieties, although of greater length of culm than the beardless, decreased less in length by close seeding than the beardless varieties.

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[1] A. E. Grantham, Tillering as a Factor in Determining the Desirable Qualities of Winter Wheats, Proc. Am. Soc. Agron., 4: 75–81, 1912.

A study of the length of spike shows that the bearded varieties under thin seeding averaged 5.66 cm. and under thick seeding, 4.03 cm., a difference of 1.63 cm. or 28 percent. The beardless varieties under thick seeding, 3.01 cm. a difference of 2.03 cm. or 67 percent. This shows a much greater decrease in head length among the beardless varieties. The difference in effect between medium seeding and thick seeding on length of spike is .88 cm. or 21 percent for the bearded and 1.48 cm. or 40 percent for the beardless wheats. While the decrease in length is not so great between medium and thin seeding, yet the bearded varieties are less affected by the increased competition.

The yield of grain from twenty-five heads from each of the different rates of seeding shows some marked variation. Under thin seeding the bearded varieties made an average of 15.4 grams from twenty-five heads; under medium seeding, 12.5 grams, a difference of 2.9 grams or a decrease of 18 percent. The difference in yield between thin seeding, 15.4 grams, and thick seeding, 9.6 grams, is 5.8 grams or a decrease in yield of 37 percent. The difference between medium seeding, 12.5 grams, and thick seeding, 9.6 grams, is 2.9 grams or 23 percent decrease.

Among the beardless varieties the yield of 25 spikes under thin seeding is 13.2 grams; under medium seeding 8.6 grams, or a difference of 4.6 grams, a decrease in yield of 34 percent. The yield between thin seeding, 13.2 grams, and thick seeding, 4.2 grams, is 9.0 grams or a decrease of 68 percent. The difference between medium seeding, 8.6 grams, and thick seeding, 4.2 grams, is 4.4 grams or a decrease in yield of 51 percent.

The effect of different rates of seeding on the size of kernel is not especially significant, although the bearded varieties, on the average, show less variation in size of kernel between thick and thin seeding than do the beardless. The kernels from the thick seeding of the bearded varieties are as heavy as under the thin seeding.

The average number of culms per plant under the thin rate of seeding in the bearded varieties was 3.28 culms as against 2.49 for the beardless. While the bearded wheats have practically the same number of culms as the beardless under the thick rate of seeding, yet there is more than three times as great decrease in yield between thick and thin seeding in the respective types. This indicates that the bearded varieties, even under severe competition, are able to mature the grain to better advantage than the beardless. The bearded varieties show a much greater tendency to expansion as expressed by tillering, when more space is allotted the plant.

In Table 2, the effect of different rates of seeding upon the length of culm, length of spike, and yield of grain is expressed as follows:

TABLE 2.—*Percent Decrease in Length of Culm and Spike and in Yield of Grain under Different Rates of Seeding.*

Rate of Seeding.	Bearded Wheats.			Beardless Wheats.		
	Culm.	Spike.	Grain.	Culm.	Spike.	Grain.
Decrease between:						
Thin and medium seeding	3%	13%	18%	9%	12%	34%
Medium and thick seeding	5%	21%	23%	0	40%	51%
Thin and thick seeding	8%	28%	37%	11%	67%	68%

These results indicate that there is a great difference in varieties as to the effect produced by the competition induced by the different rates of seeding. It appears that the beardless varieties are less able to withstand the heavier seeding.—A. E. GRANTHAM, Delaware Experiment Station, Newark, Del.

CHECK PLATS—A SOURCE OF ERROR IN VARIETAL TESTS.

A common method of correcting errors in varietal tests is to include check plats of a standard variety at stated intervals and raise or lower the yield of a given variety accordingly as the yield of the nearest check is below or above the average of all the check plats.

Different methods of computing the corrections are in use depending upon the assumption that the variation of soil from plat to plat is either gradual or abrupt. While it is usually recognized that either method is faulty, many experimenters think it better than using no checks at all and assuming that the soil is uniform.

The purpose of this article is not to discourage the use of the check plats entirely but to call attention to an error that, instead of being eliminated, may actually be introduced by computing yields in this way.

For example, a series of plats may be used for varietal tests in which there is a progressive variation in soil moisture content from one end of the series to the other. Such a variation might be due to any one of several causes, as slope of surface, texture of soil, unequal drainage or drifting of snow, etc. We may assume that the stored water in the high-moisture end of the series, together with the rainfall during the season, is sufficient to mature a maximum crop of any of the varieties grown, and that the stored water in the low-moisture end of the series, together with the rainfall, is sufficient to mature a maximum crop of only those varieties, which, because of early maturity or other reasons, require a minimum supply of water.

It is evident that any one of several varieties may be selected for growing on the check plats. Suppose then that a variety with the minimum water requirement be used. Other things being equal, all check plats will then produce practically equal yields, since the moisture content of the soil does not greatly influence crop growth as long as the supply is ample and yet not enough to reduce the supply of air in the soil so that the latter becomes a limiting factor. The series of plats would then be thought uniform and no correction would be made.

Suppose, on the other hand, a variety requiring the maximum amount of water is selected for growing on the check plats. The yield then would be cut short on those plats containing the least amount of water but would reach the maximum at the opposite end of the series. Corrections would then be made on the basis of this variation, although, as a matter of fact, the ground was uniform as far as its effect on the yield of the first variety is concerned.

That the above is not purely hypothetical appears clear from some results secured in 1912 at the Bellefourche Experiment Farm, located in western South Dakota. In that season, which was very dry, twelve varieties of barley were sown in fiftieth-acre plats, nine of them being replicated five times. By this method, the plats of all varieties were evenly distributed over the experimental area, so that any extensive variation in soil would affect all varieties. The tract used for this test was shown by previous trials to be quite uniform, but for some unknown reason, probably uneven drifting of snow, the growth of different plats of the same varieties was very different. An area near one end of the tract produced a fair amount of grain of most of the varieties, but at the other end most of the varieties were a complete failure, some of them producing no grain whatever. This variation was so evident that it was thought that the test was of little or no value as showing the relative value of different varieties. Since a part of the plats produced no grain whatever, they were not harvested and it is probable that a few were not harvested which would have produced a small quantity of grain on the plat borders. It is certain that all plats were harvested which would have produced more than two or three bushels of grain per acre.

The test included a Manchurian barley—Gatami (Cereal Investigations, No. 575)—which was very early and apparently did not suffer greatly for water on any of the plats. The average yield of this variety was 18.3 bushels with an extreme variation of two bushels per acre and a probable error of .68 of a bushel. The highest yield obtained from any other single plat was 14.7 bushels from Ouchac, another early variety. Of this variety, only two plats were harvested, the second producing a yield of 6.57 bushels. One plat of Odessa, an early six-row barley, produced 13.3 bushels and a second 6.35 bushels, the remaining three plats being not harvested. All plats of this variety and of Gatami were sown side by side so that the variation in soil must have been nearly alike for both. One plat of White Hull-less produced 10.68 bushels, although other plats of this variety produced no grain whatever. Five varieties were so poor that no plats of them were harvested, although such standard varieties as Hannchen and Hanna, usually considered among the best for dry land areas, were included.

The variation in yield between different plats of Gatami is low. The probable error (.68 of a bushel) is lower than is usually obtained in tests of this character on uniform ground. On the other hand, the variation between different plats of other varieties and the probable error is so high that no significance whatever can be attached to the yields of those varieties.

It must be evident to any one that if this tract had been used for a varietal test in which single plats of each variety were grown and check plats were used for correcting variations in soil, the most serious errors would have been introduced thereby, regardless of which variety was selected for growing on the check plats.

The critic may say, of course, that no one familiar with experimental work would fall into such an error of judgment. But it must be remembered that not all who are conducting varietal tests are familiar with experimental work, and it is by no means certain that even the trained experimenter, familiar with the varieties and conditions with which he is working, could detect, by observation alone, errors of like nature but smaller in degree.

It is unfortunate, of course, that all plats in the above test were not harvested for an exact determination of yield of grain and straw, even where no grain was produced, but the data as it stands seems sufficient to show the unreliability of check plats for all conditions.

It is probable that with certain special conditions in which variation in yield of check plats may be correlated with a known variation in soil texture, slope, or moisture content, the use of check plats may detect and perhaps measure this variation. Where lack of space or equipment prevents the replication of plats, the use of check plats is probably advisable, but extreme caution would seem to be necessary in using them as a means of correcting actual yields.—Cecil Salmon, Kansas Agricultural College, Manhattan, Kan.

UNIFORMITY IN EXPERIMENTAL AGRONOMIC WORK.

Success in business and scientific lines is preceded by a well-conceived, thoroughly worked out system or plan of operation. A distinct synopsis of this work stands out clearly before the successful worker and his mind becomes trained to follow that synopsis closely. In experimental and research lines probably chemistry has been reduced to more uniform methods and better standardization in forms and manipulations than any other. Years ago the organized chemists began the custom of appointing members (referees) to study methods along different lines of work and report on defects and offer suggestions at annual meetings. The appointments were made with special reference to the lines of work the appointee had in hand. This became a means of great improvement in standardization and the adoption of uniform methods. This made the results of each individual chemist, in whatever station he may have done the work, comparable with those of every other chemist working along similar lines.

It seems to the writer that experimental agronomic work has reached a stage that requires more real scientific and uniform methods, a standardization in experimental work that will put a definite value on completed work to mark every step in the development of each line of experimental work, so that progress may be true, pronounced, and definite, and we can feel confident that a new level has been reached and future work will be based upon this new level as a foundation. This will be real progress.

Although the term "agronomy" as applied to a department of experiment station work is of rather recent usage, it has hardly become a very broad one and includes many divisions and subdivisions of work with field crops. With all, however, there must be a similarity of plan and method up to a certain point, then each will take on an individuality that will give it its practical value. A standardization campaign is suggested and opinions and suggestions and discussions of the subject by members of the American Society of Agronomy should often be found in this JOURNAL to the end that standardization of methods be adopted and carefully followed. Team work by the groups of experimenters and investigators that are working along similar lines is a sure means of rapid and stable progress and in this, uniformity of methods becomes a necessity.—GEORGE M. TUCKER, Office of Experiment Stations, U. S. Department of Agriculture.

AGRONOMIC AFFAIRS.

EXPANSION IN AGRICULTURAL EXTENSION.

The final passage by Congress of the Smith-Lever Act, providing for coöperative agricultural extension in all the States, makes certain an enormous expansion of extension activities, progressive during the next nine fiscal years, beginning July 1, 1914. For the fiscal year 1914–15 and thereafter, a basic appropriation of $480,000 is made; that is, $10,000 to each State. In the second fiscal year $600,000 additional is appropriated and for seven years thereafter $500,000 is added annually to the amount of the year before. Thus, at the end of nine years the total annual appropriation will be $4,680,000. All appropriations additional to the basic $480,000, however, are to be allotted to the various States on the basis of their total rural population by the last federal census, and are further conditional on equal appropriations by the different States themselves. Supposing that all the States qualify to receive their full allotments, the total federal and State appropriations in 1922–23 and annually thereafter will be $8,680,000.

The passage of this act will inaugurate a new and splendid era of progress in bringing to every member of the rural community the benefits of recent agricultural investigation. This service deserves and must have, for its effective inception and administration, men of the highest type of ability, men of warm sympathy, of broad outlook, and of balanced judgment. The educational resources of the States will be severely taxed to provide enough young men of caliber and experience properly to carry on the expanding work. American agronomy is concerned not only with the extension teaching of the subject, but also with the reaction of the whole extension movement on investigation in general and on experimental agronomy in particular. That there will be such reaction is inevitable. In the end, the wide promotion of extension will undoubtedly lead to the great encouragement and advantage of experimentation and research. The immediate effect, however, may be to depreciate investigational agencies. Therein lies a real danger to agronomy in all of its phases.

These appropriations for extension are increasingly generous. By comparison the endowments of research may appear meager. The glamour of large financial support and the enthusiasm engendered by immediate and widespread expansion in extension work are likely to destroy temporarily the normal perspective in the agricultural vision. They may cause agronomists and others to forget the natural relation existing between research and extension. The demand on the agricultural colleges for extension workers will tend properly to incline large numbers of students toward that avenue of agricultural service. It is inevitable that many splendid men with abilities especially suited for effective original research will be drawn up in the widespread extension net to the permanent disadvantage of research. Without the vast body of experimental data accumulated during the past 25 years, and especially during the last 15 years, no really profitable extension service would now be possible. Without continued and steadily expanded encouragement of research in the years to come the extension service of the future will gradually become sterile. The swelling tide of extension can rise no higher than its investigational source. Indeed, it can not rise quite so high because of the loss of power in transmission.

Not for one moment should administrators or research workers lose sight of the fact that extension can have no other foundation than extensively planned and intensively conducted research. Agronomists engaged in experimentation or research must maintain the dignity of their profession in the face of what may even become a stampede of enthusiasm toward extension activities. They must remain firmly conscious of the worth of their work and of its fundamental value to extension. And all this must be done without prejudice, envy or resentment. They must be ever ready to give so good reason for the faith that is in them that research may maintain her present prestige. Only thus is there assurance that extension will continue to have and to use the safe basis of established fact.

DO MEMBERS WANT THEIR ENGRAVINGS?

The engravings or cuts, both zinc etchings and half tones, used as illustrations in the volumes of Proceedings and JOURNAL, have all been preserved. The accumulation is increasing and their storage seems a needless expense to the Society, as it is not likely that it will ever be necessary to reprint any of the volumes. It would be unfortunate to throw these cuts away, however, if by any chance they can be of service to the authors of the articles in which they appeared. The cuts will be returned to authors who will write, asking for them and agreeing to refund the expense of packing and postage. All persons wishing their cuts are requested to respond promptly, as these will be held only a limited time. Members contributing articles in the future are requested to state if they desire the return of cuts made to illustrate their articles at only the expense of packing and postage. This will be but a comparatively small expense in any case.

MEMBERSHIP CHANGES.

The following changes in the status of the membership have occurred. The total membership of the Society is now 380.

Memberships Lapsed.

Seventeen memberships have lapsed through non-payment of dues for 1913, as follows:

O. D. Center,
H. B. Derr,
J. A. Drake,
Guy W. Firor,
J. W. Fox,
H. K. Fung,
A. L. Harris,
W. M. Hays,
Thos. F. Hunt,
Wm. D. Hurd,
Alexis E. Lubchenco,
A. G. McCall,
J. C. McDowell,
H. L. McKnight,
Harrison E. Patten,
J. Warren Smith,
Frank T. Wilson,

New Members.

Cox, Joseph F., Agricultural College, East Lansing, Mich.
Hastings, S. H., U. S. Experiment Farm, San Antonio, Tex.
Lowry, Marion W., College of Agriculture, Athens, Ga.
Robertson, A. D., Bisbee, Ariz.
Suddath, R. O., College of Agriculture, Athens, Ga.
Tucker, Geo. M., Forest Glen, Md.

Addresses Changed.

DeTurk, Ernest, Experiment Station, State College, Pa.
Garver, Samuel, Redfield, S. Dak.
Khankhoje, Pandurang S., Wardha, C. P., India.
Macfarlane, Wallace, Gogorza, via Park City, Utah.
Morgan, G. W., Huntley, R. F. D., Montana.
Woodward, John, Experiment Station, Wooster, Ohio.
Zook, L. L., 545 North 27th Street, Lincoln, Nebr.

NOTES AND NEWS.

Director S. W. Fletcher and Agronomist Lyman Carrier have resigned from the staff of the Virginia Experiment Station.

Professor J. H. Worst, of the North Dakota Agricultural College, has announced his candidacy for the United States senatorship from that State.

Professor A. C. Hartenbower, director of short courses at the Oklahoma Agricultural College, has accepted the superintendency of the Guam Experiment Station, under the U. S. Office of Experiment Stations, and sailed for the Island of Guam about June 1.

Dr. L. J. Briggs, biophysicist of the U. S. Bureau of Plant Industry, has accepted an invitation from the British Association for the Advancement of Science to attend its meetings, to be held in Australia and New Zealand. His expenses are paid by the governments of those countries. Dr. Briggs will sail about July 1 and be absent until October.

Mr. C. S. Scofield, of the Office of Western Irrigation Agriculture, sailed on June 23 for England and France to investigate for the U. S. Bureau of Markets the spinning of long staple cotton, with reference to the development of the industry in our Southwestern States. He will be absent about six weeks.

It is reported that the positions held by President J. H. Connell, Extension Director B. C. Pittuck, and Agronomist O. O. Churchill, of the Oklahoma Agricultural College, have recently become vacant following the action of the State Supreme Court in upholding the legality of the Board of Regents, appointed by Governor Cruce.

The Graduate School of Agriculture.

The sixth session of the Graduate School of Agriculture will be held at the College of Agriculture of the University of Missouri at Columbia from June 29 to July 24. The agronomy schedule will occupy the lecture hour from 9:30 to 10:30 A. M. for the entire four weeks of the session, while seminars will be held from 3 to 5 P. M. on Thursday and Friday of each week.

The four lecturers, each of whom will take charge of the work for one week, are all members of the American Society of Agronomy. The first week Dr. H. L. Shantz, physiologist in the U. S. Bureau of Plant Industry, will lecture on "The Relation of Moisture Supply to

Plant Development." During the second week Director C. E. Thorne, of the Ohio Experiment Station, will present "Practical Aspects of Fertility Investigations." During the third week Prof. C. V. Piper, Agrostologist of the U. S. Bureau of Plant Industry, will lecture on "Factors of Crop Production with Especial Reference to Forage Plants." During the fourth week Dr. L. H. Smith, of the Department of Plant Breeding, Illinois College of Agriculture, will present "Crop Production Studies with Special Reference to Improvement through Selection."

The attention of the members of this Society is also directed to the conference on methods of instruction in agronomy. On Wednesday evening, July 15, Prof. A. G. McCall, of the Department of Agronomy of the Ohio State University, leads the conference on "Methods of Instruction Relating to Soils." On Friday evening, July 17, Mr. C. R. Ball, agronomist in the U. S. Bureau of Plant Industry and secretary of this Society, leads the conference on "Methods of Instruction relating to Field Crops."

COMING EVENTS.

Under this caption it is proposed to keep a standing schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

AMERICAN SOCIETY OF AGRONOMY.

Special meeting, Hays, Kan., July 8–10, 1914, in connection with the meetings of the Great Plains Cooperative Association.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Philadelphia, Pa., Convocation Week, 1914–15.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.

Annual Meeting, Chicago, December 28–30, 1914.

AMERICAN SOCIETY OF MILLING AND BAKING TECHNOLOGISTS.

Annual Meeting, Washington, D. C., November, 1914 (in connection with the Association of Official Agricultural Chemists).

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.

Annual Meeting, Washington, D. C., November, 1914.

GRADUATE SCHOOL OF AGRICULTURE

University of Missouri, Columbia, Mo., June 29 to July 25, 1914. Conference on Methods of Instruction in Agronomy:

(*a*) Soils, Wednesday, July 15, 8 p. m.
(*b*) Crops, Friday, July 17, 8 p. m.

GREAT PLAINS COOPERATIVE ASSOCIATION

Hays Branch Station, Hays, Kan., July 8–10, 1914.

INTERNATIONAL DRY FARMING CONGRESS

Annual Session, Wichita, Kan., October 7–17, 1914.

LOCAL SECTIONS.

CORNELL UNIVERSITY AND EXPERIMENT STATION.

President, Millard A. Klein.
Secretary,——————————.

KANSAS AGRICULTURAL COLLEGE AND EXPERIMENT STATION.

President, W. M. Jardine.
Secretary-Treasurer, C. C. Cunningham.

WASHINGTON, D. C.

President, W. W. Burr.
Secretary-Treasurer, F. D. Farrell.

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SOME OBSERVATIONS ON THE AGRICULTURAL CONDITIONS OF GERMANY, FRANCE, AND ENGLAND.

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EXPERIMENT STATION, EAST LANSING, MICH.

In connection with graduate studies abroad, the writer took opportunity to look somewhat into the agricultural conditions of the above-mentioned countries.

The information contained herein was obtained from visits to different agricultural regions of each country, from personal interviews with farmers and teachers in various agricultural schools, and from official reports.

For convenience of comparison, greater usefulness and better understanding, the data are presented in a summarized form, intended to give only a general idea of the average agricultural status. The disadvantage of such a procedure, however, in view of the magnitude and nature of the subject, is readily realized, but it is believed that the accounts here communicated give a true general characterization of the mean agricultural conditions of the respective nations.

GERMANY.

Agriculture in Germany plays a leading rôle. Of the total area of the country over 90 percent is classed as productive, 64.8 percent of which was farmed in 1900. Of this, 48.6 percent was occupied by land under tillage, 11.00 percent by meadow, 5.00 percent by pasture and 0.20 percent by vineyard. The population engaged in agriculture constitutes about 12 percent of the total.

The agricultural land is divided into comparatively small holdings, with a few very large, and the farming is done on an intensive scale. Table 1 shows the division of the land:

Table 1.—*Number and Size of Farms.*

Size of Holdings.	Number.	Percent of Total.	Total Acreage.	Percent of Total.
Up to 1.25 acres	2,084,060	36.30	1,547,915.0	1.4
From 1.25 to 5 acres	1,294,449	22.6	4,682,340.	4.4
" 5 to 12.5 acres	1,006,277	17.5	10,766,052.	10.0
" 12.5 to 50 acres	1,065,539	18.6	34,421,302.5	31.9
" 50 to 225 acres	262,191	4.6	31,557,527.5	29.3
" 225 to 1,250 acres	20,068	0.3	15,996,077.5	14.8
" 1,250 and over acres	3,498	0.1	8,795,250.0	8.2

It will be observed that 47.7 percent of the agricultural area is farmed in holdings of less than 50 acres. The number of these holdings is very large, being 74.4 percent of the total. The largest part of these holdings is situated in southern Germany, as in Bavaria, Württemberg, Baden, etc., and is devoted to the production of crops requiring intensive care. The holdings ranging from 50 to 225 acres constitute 29.3 percent of the total area and 4.6 percent of the total number, while the holdings from 225 to 1,250 acres and over represent 23.00 percent of the total acreage with only 0.4 percent of the total holdings. Most of these large estates are found in the Prussian Provinces of Pomerania, Posen, Saxony, Mecklenburg, and in East and West Prussia.

Farming in Germany is largely proprietary. More than 85 percent of the land is farmed by owners and only about 12 percent by tenants. A considerable amount of the rented land belongs to the Government. The land is rented, as a rule, on an 18-year lease, and the rent is commonly paid in cash. The amount of rent paid per acre varies with location, quality of land, and buildings, but on ordinary land and in certain sections of the country the rates may range from $3 to $20 an acre. Besides the regular rent, the tenant pays insurance on buildings, and church and road taxes, which amount sometimes to more than $1.00 per acre. The tenant guarantees to keep the land, buildings, etc., in very good condition. In the case of the government domains and sometimes even of the private domains, the estate is inspected every year by a committee of three to see that everything is in good order. In some of the private domains the tenant is compensated when he leaves if he has improved the fertility of the land.

With the exception of lower Saxony and of some of the large domains, the farmers throughout Germany live in villages and not upon the land. The size of the villages, shape and standard of buildings, etc., vary considerably throughout the country. As a rule, the villages have from 50 to 200 houses, and give the impression of a strong community life. The houses are very close to each other and look very simple. They are usually made of brick, probably with a wooden framework on the walls, and are either rectangular or square in shape and with one or two stories. Their roofs consist generally of tile or slate. With the exception of the buildings of the large farms, which are usually excellent in every respect, the majority of the houses in most villages are poor. They are old, inconvenient, crowded, and with bad sanitary surroundings. Those houses which are rather rectangular and have one floor are usually divided into three parts, the first or front part is occupied by the family, the second or middle portion by the animals, and the rear or third part by the tools, hay, etc. Those houses which are rather square and have two stories, are divided into two parts, the upper part or second floor is occupied by the family, and the lower part or first floor, by the animals, hay, etc. This latter form of house, however, is not very prevalent. Another very common arrangement consists of a single house with one or two stories, rectangular or square in shape, in which only the family lives. Opposite to this house, but farther back, is the barn, and the back space between the house and the barn is occupied by a wooden shed under which the implements are kept.

On account of the insufficient room and crowded condition of the buildings, the sanitary environment, in most houses, is not very good. For instance, in many places, the manure and other rubbish are thrown directly in front of the main entrance which may be in front of the house and next to the road, or at one corner or center of the court which is situated at the side or front of the house.

The German farmers, on the whole, take rather good care of the liquid manure, but in the main, not so of the solid. The latter is allowed, by a great number of them, to remain in the yard for a long time, loose and unprotected, and nearly all of them apply it on land in heaps and generally a long time elapses before it is spread and turned under. As one travels through the country he sees constantly field after field with manure in heaps. When there is no more room in the yard and no land on which they can apply it immediately it is piled, and generally compacted, at one corner of the field which is to be manured, and finally covered with a layer of soil to prevent the rapid loss of nitrogen. Most of the large farmers, and the better class of the small, have the manure pile in the yard, trampled by animals. The loss of nitrogen from the heaps on the field and from the piles in the yard through volatilization is undoubtedly large, but the loss of nitrogen, as well as of phosphorous and potassium compounds, through leaching in the yard, is very small because nearly every farmer has made some kind of an arrangement to catch the leachings and the urine separately. The arrangements made for this purpose vary among the different farmers. Three examples, however, will probably suffice to give an idea. The first and most common system among small farmers is to construct a cistern in front of the house and next to the road, and then connect it to the stable, and if possible also to the manure pile, by means of a conduit. When the cistern is filled with the urine, the latter is pumped into a barrel, or sometimes on a load of manure, by a stationary pump, or brought up by buckets. The second arrangement consists of a rectangular pit with a falling inclination, and probably with an impervious bottom. The manure is piled upon this pit. The urine which drains from the pile and that which comes directly from the stalls through the conduits, is gathered at the steepest and deepest part of the pit, at which point a pump is installed. If the ground is very level, then a third arrangement is very common. This consists of a round basin, with a cistern at the center or one side. The manure is piled upon this basin. The urine collects in the cistern and is pumped out whenever necessary and applied to land. As a rule, it is applied to the meadow land and is spread in various ways. One of the most common methods is to allow it to run out from the end of a barrel as the latter is moved over the field.

With the exception of most of the large domains, and of certain farms in lower Saxony, the land of each farmer is generally not only a long distance from the village and consequently from the residence, but also it is divided and scattered around the district. For instance, a farmer may possess 50 acres of land in several different portions, situated at different places. This subdivision and scattering has been brought about through inheritance of parental estate, intermarriage, purchase, or gift. It is, however, of great economic disadvantage because the loss of time it entails is enormous. Besides, it has caused considerable inconvenience and bad feelings among the neighboring farmers due mainly to the necessity of trespassing on account of lack of proper paths. The disputes grew so serious in many districts that the Government undertook, a few years ago, to ameliorate conditions by passing a law providing for land combination and redistribution. According to this law any village, by vote of three fourths of its inhabitants, can have all its land combined or thrown together and then redistribute it, by special commissions, into larger pieces. This law seems to be very successful and satisfactory as the majority of the villages have already tried it. When a village decides to have its land redistributed it notifies the government of the fact. The government then sends expert surveyors to make a very detailed map of the region, showing extent and location of each farmer's land, etc. After proper paths have been laid out, the land is then valuated by special commission composed of trained agriculturists. Each farmer then receives land of as much the same area and quality of his original as possible, either in one big piece or in few large portions. If a farmer receives land of poorer quality than the original, he is compensated either in money or in more land. The expenses accruing in this operation are borne both by the government and the village.

In those districts where holdings are small, the fields farmed by different people are long and narrow. When these fields are under crop they present a very interesting sight—they resemble the experimental plots of some of the stations in this country. Each farmer may be growing on his plot an entirely different crop from that of his neighbor. For instance, it is not uncommon to see seven long and narrow strips of land under seven or more different crops. Some of these fields, in the midst of others, may be divided into two or three parts, each part planted to a different crop.

Fences are almost unknown in Germany. The only sign which indicates the boundaries of the different fields is a stone which is almost buried in the ground.

The roads are excellent throughout the country and are kept in good condition. They are much narrower than those in America and, as a rule, are always lined on both sides either by fruit or ornamental trees. These trees are a property of the village and not of the individual; and in the case of the fruit trees, the fruit is sold at auction and the money obtained is turned into the village treasury.

The land in Germany is worked exceptionally well. Almost every farmer seems to spare no time and pains to give the soil the best preparation and care under his command. The winters in Germany are generally not very severe. The soil, therefore, freezes late or not at all, and thaws very early and consequently it receives extra work. As a rule, the land is plowed at least twice, once shallow and once deep, and rolled, disked and harrowed several times. Many of the large domains afford excellent examples of intensive tillage on a large scale.

Besides giving the soil excellent cultivation, the German farmers are great believers in fertilizers and fertilize the land rather heavily. Nearly every farmer attempts to treat his land with a heavy dressing of farmyard manure as often as possible, but at least once every three years, and with commercial fertilizers every year if the system of rotation permits it. Table 2 gives the names and a rough approximation of the total amounts of the different fertilizers used in 1909.

TABLE 2.—*The Consumption of Fertilizers in Germany.*

	Tons.
Superphosphates	1,250,000
Basic slag meal	1,718,231
Salts of potassium	240,000
Nitrate of soda	609,170
Sulphate of ammonia	339,409

Nearly all the farmers keep live stock and they generally get plenty of dung. Some of them collect droppings on the streets and roads and also the mud or dirt that accumulates. The latter is usually first composted and then applied to meadowland. In most cases the night soil also finds its way into the land. Most of the farmers have made arrangements whereby it is conserved and applied together with the farmyard manure.

The large farmers spread commercial fertilizers with the fertilizer spreader, but the small farmers by hand. Both classes of farmers, however, with few exceptions, spread farmyard manure with a fork. It is first piled, as has already been mentioned, in heaps about 5 meters apart and then spread over the land evenly.

The large farms in Germany are very extensively equipped with agricultural machinery and other farm conveniences. The small farms, however (and these constitute the bulk of the total agricultural area), are very incompletely equipped with farm machinery. Indeed, it can be said that the small farmers are still behind in the employment of general agricultural implements. For instance, practically all of them still harvest with the sickle, spread manure by hand, and most of them still sow grain and dig potatoes by hand, collect and spread hay with a fork, thresh with the "Göpel," i. e., a simple threshing machine run by a lever with animals. The adoption of machinery, however, is taking place rather rapidly. Some of the more expensive machines, such as threshers, harvesters and even sometimes the seeders are being introduced by cooperative societies or by private concerns, and rented to individual farmers.

It might be remarked here in passing that some of the farm machinery used in Germany, as well as in France and England, is of American make. The most prevalent pieces are the self-binder and the mower.

Since the employment of machinery is very limited on the small farms, a great amount of the farm work is necessarily done by hand and animal labor. The hand labor is performed mostly by the family and by hired women. At the busy parts of the year it is not uncommon to see the whole family working in the field. Female hand labor is used very extensively. One sees constantly women working in the field and very often in large numbers. The writer has seen as many as eleven spreading hay, twenty digging potatoes, and over fifty harvesting sugar beets. In the busy seasons when the demand for hand labor is high, large armies of these women come into Germany from Poland. The price of the hand labor varies with the section of the country and with the season. In summer time, in most sections, the men, hired by the day, get from about $.75 to $1.00, and women somewhat less. The farm laborers hired for the year may receive a salary of about $200, a house in which to live, and such provisions as milk, potatoes, beans, or other products.

The animal labor on the small farms is done mainly by cows. This includes the working of the land, and drawing of wagons. In southern Germany it is very common to see a plow pulled by one, two or more cows, or a combination of one cow and a horse, a mule or an ass, and with one man leading them and one guiding the plow. On the larger farms, and especially in northern Germany, the animal labor is performed largely by horses and oxen. The writer saw many fields in northern Germany being worked either exclusively by oxen or horses, or sometimes a combination of the two. He saw one field ploughed with six teams of four oxen with two men to each team.

There is a large number of systems of rotation practiced throughout the country, but the two most extensively employed are (1) the "verbesserte Dreifeldwirtschaft" which consists of:

(*a*) Root crops,
(*b*) Wheat,
(*c*) Rye,
(*d*) Clover,
(*e*) Wheat,
(*f*) Barley, and

(2) the "Fruchtwechselwirtschaft" which consists of:

(*a*) Sugar beets,
(*b*) Wheat,
(*c*) Clover,
(*d*) Rye.

The most important crops of Germany are rye, oats, wheat, barley, sugar beets, and potatoes. The cereal crops are cultivated practically in all parts of the country but in the south and west wheat is predominant and in the north and east rye, oats, and barley. In the production of sugar beets, Germany holds the first place in the world. The sections which are preëminently adapted for its growth are Schlesien, Posen, Anhalt, Braunschweig, etc. Potatoes are grown mostly in the provinces of Prussia, and in Bavaria. The largest quantity and best quality of wine is produced along the Rhine. Table 3 contains the average yields per acre of only those crops which can be used for comparison in the different countries under consideration:

TABLE 3.—*Average Yield Per Acre of Crops in Germany.*

Crops.	Yield per Acre. Mean of 5 Years. Prior to 1912.
Wheat	30.01 bushels
Barley	35.37 "
Oats	44.08 "
Rye	25.85 "
Potatoes	5.22 tons

Considering the average yields per acre of the same crops in all countries, it will be seen at once that the foregoing yields are quite high. This large average production is undoubtedly due to the intensive working and heavy manuring and fertilizing of the land. These high yields, combined with great economy, tend to make the farming population of the country quite prosperous. There are many farmers, of course, who are ignorant, incapable, or under very unfavorable circumstances, and who manage to make only a bare living but the greatest numbers of them are thrifty. It is true that the majority of the small farmers are not obtaining as high net returns from their farms as they should were they practicing more economy of time and labor. In this respect, however, they cannot be severely criticized, because of the economic conditions and unfavorable circumstances which prevail. The average German farmer is capable, intelligent, and well educated in his business, and he would practice a better kind of farming if general conditions were different. The large farmers, on the other hand, are getting very high returns for their labor and investment because they have all the advantages, and as a rule, they are university graduates and conduct their farming enterprises in a very scientific manner. Many of these large farms are wonderful examples of a high type of farming.

Germany is very strong in agricultural education. As the list below shows, it has a large number and variety of schools offering instruction of various grades in agriculture. These schools may be best arranged in the following order:

Type.	Number.
Agricultural institutes in universities	8
Agricultural professors in universities with no agricultural institution	1
Agricultural institutes in technical institutions	1
Agricultural secondary schools	26
Farm schools	45
Lower schools for special subjects	43
Agricultural winter schools	279
Schools for pasture	8
Dairy schools	17
Special courses	213

The agricultural institutes in the universities are the highest institutions of agricultural learning, and offer courses of advanced and scientific nature, leading to the degree of Doctor of Philosophy. The farm schools give instruction to farmers' sons on the fundamental elements of agriculture. The course consists of three continuous terms of six months each. The instruction is general, elementary, practical and basic. This class of schools, however, is constantly decreasing in number and is being replaced by the winter agricultural schools which give essentially the same instruction but of only two winter terms of six months' duration. These schools are becoming very popular and serviceable and are rapidly multiplying. The pupils are usually sons of the small farmers. They are generally young and have received only an elementary education when they enter. A great number of the present farmers have studied in these schools when they were boys. Only part of the teachers are permanent and devote all their time to these schools. The others are visiting teachers from other schools. During the time instruction is stopped the permanent teachers travel through the country and conduct general extension work, and also try to induce the various farmers to send their sons to winter schools.

FRANCE.

France is preëminently an agricultural country. Of the total population more than 57 percent is rural or depends for its livelihood upon the land, although only about 22 percent is directly engaged in agriculture. Of the total area more than 93 percent is classed as productive, of which 94.80 percent was, in 1909, under the plow, 1.94

percent in meadow, 2.09 percent in herbage and pasture, 0.68 percent in vineyard, and 0.49 percent in miscellaneous crops.

The agriculture of France does not differ very essentially from that of Germany. As in the latter, the land is divided into comparatively small holdings, with a few quite large, and the farming is done on a rather intensive scale. Table 4 shows the manner of land division as given by the Minister of Finance in 1908.

Table 4.—*Number and Size of Farms in France.*

Size of Holdings.	Number.	Percent of Total.	Total Acreage.	Percent of Total.
Less than 2.5 acres.......	2,087,851	37.95	3,071,492.5	2.80
From 2.5 to 23 acres.....	2,523,713	45.78	28,898,355.0	26.34
" 23 " 90 "	745,862	13.56	37,063,245.0	33.79
" 90 " 225 "	118,497	2.17	40,676,390.0	37.07
More than 225 "	29,541	.54		
Total.................	5,505,464	100.00	109,709,482.5	100.00

A glance at the above table reveals at once the fact that the farms in France are comparatively small. It will be seen that 62.93 percent of the total acreage consists of holdings, ranging from less than 2.5 acres to 90 acres. The number of these holdings constitutes 97.29 percent of the total. The farms which vary from 90 to 225 acres and over contain only 37.07 percent of the total acreage and only 2.71 percent of the total number of holdings.

About 80 percent of the total holdings, which amount to about 60 percent of the arable land, are farmed by proprietors; of the rest approximately 13 percent are leased, and about 7 percent are worked on the system known as "metayage," i. e., the division of the produce between the owner and tenant. The length of period of renting is not uniform but in the majority of cases it is below 10 years.

In general, the farmers live in villages as in Germany, and not upon the land. There is a great number of them, however, both large and small, in all the different sections of the country, who live upon the land, and it would appear that the number is much greater in France than in Germany. As in the latter country the land of each farmer is divided into several small pieces. These are scattered all over the district and in most instances at considerable distance from each other and from the residence. Unlike in Germany, the fields are fenced, but not very extensively and completely. The fences consist of stone, wood, wire and hedges. The latter form predominates. The roads are very good, but are not ornamented with trees on the sides so extensively as in Germany.

The villages are in all sizes and forms. The style and standard of the houses vary considerably in the different regions, and even within the same region. The rather ancient and most predominant form consists of a simple, square or rectangular brick or stone house, with one or two stories, connected to a series of other buildings such as the barns, implement house, etc., made of the same material as the house, or sometimes of wood, and arranged in a square shape and forming a court in the center. A high wall connects all these buildings in a complete enclosure. An entrance to the buildings, therefore, can be gained only through the gate. The wall is generally very high, and nothing in the interior can be seen from the outside. In the center or at a corner of this court is piled the manure. The residence may be located at the front or at the side of the square. The villages which are composed mainly of this style of buildings present a very interesting sight. Each enclosure may have 3, 4 or 5 buildings on the line of the square, giving the impression of or suggesting a community. The other form of houses which are very common throughout the country are rectangular or square in shape with one or two stories. The rectangular and single-floor houses are divided into three parts. The first or front part is occupied by the family, the second or middle part by animals, and the third division by hay and implements. Probably at a corner in front of the third part of the house is piled the manure. In the square form and double-story house, the family lives in the upper floor and in the lower are housed the animals, machinery, and hay. In this case, the manure is commonly found very close to the main entrance. On the whole the houses of the majority of the smaller farmers are poor. They are old, poorly arranged, and possess almost no modern conveniences. The sanitary conditions and environment in many, if not in most cases, are bad. There are, on the other hand, many farm buildings throughout the country and especially in the northern sections, which resemble in arrangement the best farm buildings in America, and which are very modern, and possess all the best and up-to-date conveniences. Such buildings, however, are mainly found on the large estates.

The farming in France is on the whole intensive. Most of the land is worked very well. As a rule, it is cultivated at least twice—once shallow and once deep, and rolled, harrowed, etc., several times. In spring it is a common practice to harrow and roll the land planted to cereal crops when the plants have about 3 or 4 leaves. The principal object of this practice is to settle the ground and level the surface and thus facilitate harvesting. The land is manured and fertilized quite liberally. Nearly all the farmers keep animals and they attempt to treat their soil with a heavy dressing of dung as often as possible, but at least once every three years. The farmyard manure is put upon the land in heaps at a distance of about 5 meters apart and then spread evenly with a fork. A large quantity of commercial fertilizer is employed but not so much as in Germany as shown by Table 5, taken from the journal "L'Engrais" for February, 1910.

TABLE 5.—*Kind and Quantity of Fertilizers used in France and Germany.*

Kind of Fertilizer.	France.	Germany.
Superphosphates	1,500,000 tons	1,250,000 tons
Basic slag meal	250,000 "	1,718,231 "
Various phosphates	200,000 "	?
Salts of potash	15,000 "	240,000 "
Nitrate of soda	263,580 "	609,170 "
Sulphate of ammonia	81,311 "	339,409 "

Although these figures are only rough approximations, they can be depended upon to show in a general way, the difference in the use of commercial fertilizers between the two countries. It will be seen that the total quantity employed in Germany is almost twice that in France even though the extent of the agricultural land is about the same in both countries. The writer met many farmers both in the good and the poor sections of the country, who used no commercial fertilizers and had no faith or confidence in them. They believed that farmyard manure is the best fertilizer and if they could apply enough of this on their land they would not need to resort to the artificial. The small farmers spread the commercial fertilizers by hand while the large farmers mostly use a fertilizer spreader. Both classes of farmers, with few exceptions, spread the farmyard manure with a fork after it is applied on the land in heaps. On the whole the French farmers do not take very good care of either the solid manure or the liquid. The majority of the small farmers and many of the large have made no arrangement to catch the urine separately, as is the custom in Germany, and consequently this part of the animal excreta may be lost if it is not taken up by some absorbing substance. Many of the small farmers have dug a small pit near the manure pile into which the liquid manure runs, and when it gets filled the liquid is carried to the field in barrels, or sometimes in buckets if the field is very near. If the land happens to be around the house the urine is allowed to run into it.

The employment of modern farm machinery is not yet very complete and perfect in France. The occupiers of the large holdings are, as a rule, very up-to-date and employ all the best and necessary implements but the small and average farmers, and especially in certain sections of the country are still quite behind in the employment of general agricultural machinery. In some departments such as the Côte-D'Or, Côtes-Du-Nord, Seine, Seine-et-Oise, etc., the use of machinery is quite general and complete both by the small and the large farmers. In such departments, however, as Morbibam, Haute-Vienne, Corrège, Lozère, etc., not many of the modern convenient implements are employed. In many of these departments the sowing and harvesting machines are rare, and in some the threshing machine is almost unknown. The latter machine, however, is being introduced now in almost all the sections of the country by private undertakings and cooperative societies, and is thus replacing and driving away the old, slow, uneconomic and unhygienic method—the flail. Several of the other more or less expensive machines are also being introduced and hired to small farmers by private undertakings or bought and used cooperatively. In general the farmers are rather slow in the adoption of mechanical power and they do not appear to be very willing to make a transformation unless they are compelled by necessity. Many of them believe that the quality of a large part of the hand labor is superior to that of the machinery.

On account of the lack and incomplete employment of agricultural machinery an enormous amount of hand labor is necessarily applied upon the land. A large part of the hand labor is female, but not so great as in Germany. The labor wages vary somewhat with the section of the country and, of course, with the season of the year. In the busiest periods the day laborer (male) earns about $1.00 a day, while in the other parts of the year he earns somewhat less. On the whole, the wages are constantly rising while hand labor is becoming scarcer all the time. It is worth noting here that the exodus of the laborers, the sons and daughters of the farmers, and even of some of the farmers themselves, from the country and their emigration to the cities, is becoming very serious in France. It seems, however, that this is true in all countries.

The animal labor is done by cows, oxen, horses, mules, and asses. In south and central France and especially where small farms prevail, the work is mostly performed by cows and oxen. It is not very uncommon to see one, two, four or six cows and oxen hitched to one plow, with two and sometimes three men to each plow. In northern France where the land is good and the farms rather large, the animal labor is generally done by horses and oxen. The writer asked many of the farmers why they use so many oxen and comparatively so few horses for the farm work. They always replied that the oxen were more economical than the horses. They cost less to keep, give less trouble, and at the end of their lives they have more value than the horses. The oxen work slower than the horses, but they stand more work.

Because of the difficulty of securing qualified labor and on account of the belief that a large part of the hand labor is superior in quality to that of the farm machinery, the small farms, down to a certain size, are in favor and considered more profitable. It is claimed that the inherent advantages accruing from the large farms are annihilated by the scarcity of qualified labor and the large expenses involved in the maintenance of a big machinery equipment; while the disadvantage resulting to the small farms from the incomplete equipment of machinery is compensated by the better quality of the hand labor and the more intensive preparation that the soil receives. Whether the small farms are more profitable than the large is a question.

While wheat and wine constitute the staple products of the country, the French agriculture is distinguished for the variety of products it produces. For comparison with the other two countries, Table 6 presents the average yield per acre of only the chief cereal crops and potatoes. The figures for Germany are shown here for convenient and direct comparison.

TABLE 6.—*Average Yields per Acre for the 5 years Prior to 1912.*

Crops.	France. Average Yields per Acre, Bushels.	Germany. Average Yields per Acre. Bushels.
Wheat	19.47	30.01
Barley	23.45	35.37
Oats	30.27	44.08
Rye	16.25	25.85
Potatoes	3.56 tons	5.22 tons

By comparing the two columns it will be readily seen that the average yields per acre of all the above crops are far greater in Germany than in France. This difference in the relative production may be due to several causes, but a large part is undoubtedly due to the less general progress that the French farmers have made in the introduction and use of the modern machinery, and the adoption of the best and up-to-date cultural methods. The French farmers, however, are, on the whole, quite thrifty. There are many who are ignorant, incapable, poor, and lead a rather uncomfortable life, but the greater part of them are prosperous. Their degree of prosperity, however, is not always indicated by their environment and mode of living, as the French farmers are extremely economical, and owe what prosperity they may enjoy largely to their simplicity of living and great saving.

The provisions made for agricultural education in France are good. The following list shows the type and number of the most important agricultural institutions:

Type.	Number.
Institute of agronomy	1
Schools of agriculture	3
School of horticulture	1
School of agricultural industries	1
Schools of diary	2
School of regional agriculture	1
Practical schools of agriculture	40
Farm schools	10
Schools of cheese-making	3
Schools of pomology	6
Departmental professors	80
Special professors of agriculture	175
Teachers having charge of agricultural instruction in the primary and secondary schools	200
Stations of agronomy and agricultural laboratories	85

On account of lack of space a brief description of only the most important of the above types of institutions can be given here. The institution of agronomy (Institut National D'Agronomique) at Paris corresponds to the agricultural institutes in the universities in Germany, and offers courses of advanced and scientific character leading to a degree. The period of instruction is two years. Admission by regular students is obtained only upon passing satisfactorily an oral and written examination on subjects taught at the Lycee. The age limit is 17 years. Special students are received without entrance examination, but are restricted to the use of certain facilities enjoyed by the regular students, and also are not allowed to work in the laboratory. Several scholarships are offered in this institution as well as in these following.

The agricultural schools (Ecoles Nationales D'Agriculture) give instruction of high standard, but more of a practical nature and leading to a degree. There are only three such institutions, situated respectively at Grignon, Montpellier and Rennes. They all receive two classes of students—regular and special. The former are granted admittance only upon competitive examination. The course is of two years' duration.

The practical agricultural schools (Ecoles Pratiques D'Agriculture) receive pupils who have completed the primary school and give them instruction on the practical and elementary fundamentals of agriculture. The course consists of two or three years. These pupils have also to submit themselves to an examination for admission. The age limit varies from 13 to 17 years.

The farm schools (Fermes-Ecoles) receive young boys of about 16 years of age who act as apprentices. They perform practically all the farm work and thereby receive a practical instruction as to the best farm operations. Their stay at these schools varies from two to three years. All their expenses are paid by the government and when they complete their work and leave they receive, besides, a compensation in cash of about 300 francs ($60).

On the whole the French government is doing considerable towards educating and helping its farmers. Besides establishing this large number and variety of schools, and inducing and helping the young men financially or otherwise, to attend them, it also encourages the establishment of the various cooperative organizations, the holding of fairs, lending of money to farmers at reasonable rates, etc.

ENGLAND.

The agriculture of England is different from that of the two countries already considered. Some of the most important differences consist in the percent of land under the various categories of agriculture, the size of holdings, system of farming, etc. Because of these striking dissimilarities many very interesting comparisons can be made which in turn suggest several important agricultural economic problems.

According to the last survey, England and Wales comprise 37,138,768 acres of land, 88.4 percent of which is divided into the following categories, shown in Table 7.

TABLE 7.—*Land Under Different Categories.*

	Acres.	Percent of Total Area.
Arable land	11,058,233	29.8
Grass land	19,876,415	53.5
Woodlands	1,884,068	5.1
Total	32,818,716	88.4

It will be seen that 53.5 percent of the productive agricultural land is devoted to grass, which may be permanent or temporary. This presents a striking contrast to 16 percent of the agricultural land devoted to the same purpose in Germany, and 4.03 percent in France.

The more interesting fact is that the arable land is constantly and gradually decreasing—and has been for the last 40 years, and that the area of the grass land is increasing. There are several reasons which go to account for the reduction of the arable land, but the most important seem to be (1) unchecked foreign competition, (2) increase of cost and growing scarcity of qualified labor, (3) less risk and outlay involved in farming grass land, and (4) less remuneration of the arable farming under present conditions.

The percentage of the total population engaged in agriculture is small in England in comparison with that of the other countries. For England and Wales it is only about 3 percent and for the whole United Kingdom it is about 4.5 percent.

Another interesting comparison is the size of land holdings. It has been seen that in Germany and France the small holdings predominate over the large. In England it is just the opposite, as Table 8 shows.

TABLE 8.—*Number and Size of Holdings.*

Size-Group.	Number.	Percent of Total.	Total Acreage.	Percent of Total.
Over 1 and not over 5 acres.	92,302	21.18	284,945	1.05
" 5 " " " 20 " .	122,117	28.03	1,373,277	5.06
" 20 " " " 50 " .	78,027	17.91	2,623,304	9.67
" 50 " " " 100 " .	59,287	13.61	4,324,724	15.94
" 100 " " " 150 " .	31,838	7.31	3,942,165	14.53
" 150 " " " 300 " .	37,593	8.63	7,844,200	28.92
" 300 acres.	14,513	3.33	6,736,767	24.83
Total.	435,677	100	27,129,382	100

The above table shows conclusively that large farms predominate in England. It will be seen that 53.75 percent of the agricultural land is farmed in holdings from 150 to 300 acres and over. The holdings ranging from 50 to 150 acres and from 20 to 50 acres represent 30.47 percent and 9.17 percent of the total acreage respectively. The number of holdings of from 20 acres and over represent 49.79 percent of the total while the number of holdings of from 1 to 20 acres constitute the remainder 49.21 percent, but only 6.11 percent of the total area. A large part of these small holdings is in gardens or plots devoted largely to the production of crops requiring an intensive management. A considerable part is also used as land of accommodation held by persons mainly employed in other vocations than farming. The large farms are in most favor. The general opinion and belief seems to be that on ordinary land only farming on a large scale can pay. It is claimed that a large farmer with big capital can perform many farm operations more economically than a small farmer can, and thereby secure greater net returns. Furthermore, an intensive large farmer obtains bigger net profits than a small intensive farmer. On the other hand, where the land is very rich, and the soil and other conditions are suited to certain crops which require very intensive care, the small farms are advocated, and, as a rule, prevail.

The general preference in England for farming large exploitations is, in the main, contrary to that of France and Germany. The experience and results of the latter countries seem to indicate that farming on a small scale is more profitable. The disagreement, however, goes to show that the success of these two types of farming depends upon many factors, which may not exist everywhere.

In contrast to the division of land and scattering of the fields in Germany and France, the land of each farmer in England is almost always together and nearly in every case fenced. The fences consist of stone, wood, wire, but largely of hedges. This latter mode of fencing causes considerable waste of land. The English farmers, however, do waste, in various ways, an enormous amount of land, which in Germany and France is almost a rare thing.

One of the most interesting things about the British agriculture is that it is one of tenancy. More than 87 percent of the agricultural land is held and farmed by tenants and only 13 percent by owners. This is, without question, an illogical system, and considering with what distrust it is held in many countries, one would easily conclude that the British soil would soon be ruined. The significant truth about the matter is, however, that this system has been in operation for the last century or more and judging from results it has worked remarkably well, and has kept the productivity of the land to an exceptionally high degree. Probably the character of the people and the nature of conditions favor the successful operation of this system. In the first place, the largest part of the land is owned by a few rich people who rent it to selective farmers of ability, experience and capital under the supervision of managers or agents. The terms of renting are very advantageous to the tenants. They rent the land usually on yearly agreement at a very reasonable price—sometimes even below the competitive value. They are allowed to follow now any system of farming and if they improve the productivity of the land they are compensated accordingly when they leave. Under these conditions the average tenant calculates to stay on the land for a long time and tries to follow a permanent system of agriculture. As a result, nearly all the best, most advanced and skillfully adapted farming is being done by the tenants. This system apparently works so satisfactorily and advantageously for the tenants that they prefer to remain as tenants. When the opportunity is presented to them to become owners of the farms which they work, even sometimes under the most advantageous terms to themselves, the most of them refuse the opportunity and remain tenants. They argue that since they are satisfied with the system under the present conditions, they do not wish to tie up their capital because they need it to conduct their farming enterprise economically and profitably. Furthermore, if they buy the land on mortgage, the interest they have to pay is almost as great as the rent.

On the whole, the English farmers are up-to-date. There are some, both of the small and large class, who are poor farmers and remain behind the times. They are slow to change their traditional methods, and make transformation only when they are compelled to do so by necessity. But the majority of them are very modern. They live upon the land and not so much in villages as in Germany and France. The majority of them possess very good houses and barns with good arrangement and modern conveniences. They live more comfortably and under more sanitary conditions and environment than the majority of the farmers of Germany and France. They employ machinery very extensively. There are probably very few who do not possess or employ all the necessary farm implements. For the animal labor they use almost exclusively the horse. They make very limited use of the female hand labor. The hand labor, however, in England is becoming also scarce. Not only that, but the country is being gradually depopulated by exodus of the young people.

The greater part of the farmers work the land quite intensively and fertilize it rather heavily, both with farmyard manure and commercial fertilizers. Since the farms are so large one would suppose that the individual farmer could not get enough of the dung to treat his land. As a matter of fact the greater part of the farmers keep a considerable amount of live stock to pasture on the enormous areas of grass land which exist in the country, and consequently they secure, as a rule, plenty of manure. In general however the English farmers do not take as good care of the manure as they might. They have made no other provision for catching the urine than by litter.

A large variety of crops grow in England. The following list in Table 9 represents the names and total amounts of the most important for the whole United Kingdom.

Table 9.—*Most Important Crops in the United Kingdom.*

Crop.	Estimated Total Production in Tons of 1913.
Wheat	1,519,000
Barley	1,465,000
Oats	2,878,000
Beans	204,000
Peas	91,000
Potatoes	7,605,000
Turnips and Swedes	25,320,000
Mangold	9,276,000
Hay (all kinds)	15,395,000
Hops	13,000

It will be seen that from the standpoint of total production the turnips and swedes hold the first place, followed successively by hay, mangold, potatoes, oats, wheat, barley, etc. The turnips and swedes, hay and mangolds are the characteristic crops of the English agriculture.

The figures for the average yields per acre of the cereal crops and potatoes for the five years prior to 1912 for the whole United Kingdom are represented below. The corresponding figures of Germany and France are also given here for convenient and direct comparison, as shown in Table 10.

Table 10.—*Average Yield Per Acre of Various Crops.*

Crops.	United Kingdom.	Germany.	France.
	Bushels	Bushels	Bushels
Wheat	32.74	30.01	19.47
Barley	34.66	35.37	23.45
Oats	42.72	44.08	30.27
Rye	......	25.85	16.25
Potatoes	5.76 (tons)	5.22 tons	3.56 tons.

A glance at this table will at once reveal the fact that the average yields per acre of the above crops are comparatively very high in the United Kingdom. They are higher in every case than those of France and higher than those of Germany in two instances. These figures are very significant in view of the fact that the farming in England and the whole United Kingdom is conducted on a large scale, while that of France and Germany is on a small scale. While these results undoubtedly indicate a very high ability of the British farmers to get the most out of the land, it should also be remembered that they possess, on the whole, good land and use for the production of these crops only the best, and the inferior for the grass—although some of them use the best land for grass. As a result of the large yields and greater net returns due to large farming, the average English farmer looks and really is more prosperous, leads a more comfortable life, and lives under more sanitary conditions and environment than the average farmer of France and Germany. That they are prosperous and that the land pays is further indicated by the fact that when a good farm becomes vacant several hundred candidates file application for it.

The agricultural education now available in Great Britain consists of residential courses at various colleges extending over three or four years, and leading to a degree or diploma; shorter courses at the same institutions; short courses varying from a few weeks to several months at farm schools and similar institutions; courses of ten days or a fortnight in dairying at migratory dairy schools which visit a number of different centers each season; and courses of a day or evening lectures, accompanied in many cases by practical instruction in agriculture, poultry-keeping, etc. A number of counties carry out field experiments or demonstrations and have fruit-growing stations, demonstration gardens or trial allotments. Agricultural research is performed in a large number of institutions.

SOME UNUSUAL SOILS THAT OCCUR IN OREGON.[1]

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At the head waters of the Des Chutes, Umpqua and Willamette rivers in Central Oregon lies what is probably the greatest pumice deposit in the world. (Pumice is herein taken to mean a glassy form of very vesicular lava.) It probably reaches its greatest thickness in the region of Beaver marsh, which lies some thirty miles south of the town of Crescent. At this point it is known to be sixty or more feet in depth. This deposit spreads over a vast area like a huge blanket. It becomes thinner as the borders are reached, gradually blending into the so-called eastern Oregon silts and fine sandy loams. The boundaries have not been accurately located, but in general, this formation occupies the area between Crater lake and Fort Klamath, the Three

[1] Contribution from the Oregon Experiment Station, Corvallis, Oregon.

Sister Mountains, the town of Bend and the westward slopes of the Cascades. It extends several miles to the east of the Walker range of mountains.

The general topography of the area is quite rough. There are, however, several portions that are unbroken and tillable. Large pumice boulders, some of which are three or more feet in diameter, are frequently met with on the surface. Numerous boulders occur several feet below the surface, as was shown in the digging of wells near Beaver marsh. Good commercial yellow pine is found in some parts of the broken districts. As a rule, jack pine predominates on the unbroken areas. The district, as a whole, furnishes poor grazing.

Numerous craters of extinct volcanoes in the Walker and Cascade mountains suggest the sources of the material that make up this deposit. The formation is recent, the particles being angular apparently have decomposed or disintegrated very little since having been blown out and deposited.

It has been estimated that there are 20,000 acres of tillable pumice soil open to entry in the vicinity of Lapine and Crescent. However, the total tillable area, including that segregated, patented and that set aside as school lands is several times this amount. The writer made a general survey of the greater portion of the pumice formation and a detailed survey of the tillable area near Lapine, during the months of July and August, 1913. Certain of the field observations and results of laboratory studies are presented in the following paragraphs.

Description of the Lapine Area.

The greater portion of the area surveyed, which is characteristic of the tillable pumice area, is known as the Des Chutes Land Company's Irrigation tract. The elevation above sea level varies from 4,200 to 4,400 feet. It lies within the angle formed by the junction of the Des Chutes river and Paulina creek. The surface is unbroken and slopes very gently to the north. Although large yellow pine trees occur locally, the land as a whole is covered with jack pine timber. The latter has no commercial value being used only for fire wood and fencing material.

The climate is variable, frosts being frequent, during the summer months. The average annual precipitation is approximately twenty inches, the greater portion of which falls during the winter months. The snowfall is variable. Occasionally deposits of four or more feet in depth occur.

SOILS.

The soils are characterized by a very loose, more or less disintegrated pumice layer which extends to depths of eight to twelve inches. Owing to the presence of more or less organic matter, the upper four inches is darker gray in color than the material immediately underneath. As a rule, a very coarse pumice layer which varies in thickness from eight to twelve inches lies below the disintegrated mass. Beneath this layer to a depth of approximately forty inches, the texture is somewhat finer. Forty inches from the surface, a reddish brown or brownish red gravelly layer occurs.

EXPERIMENTAL DATA.

Certain physical and chemical studies of these soils have been made. As was referred to previously, certain of these properties are quite unusual.

Physical Properties.—Physical analyses of numerous samples were made. The result of an analysis of a sample typical of the area is shown in Table 1.

TABLE 1.—*Mechanical Analysis of a Volcanic Soil.*

Depth of Sample.	Coarse Gravel.	Fine Gravel.	Coarse Sand.	Medium Sand.	Fine Sand.	Very Fine Sand.	Silt.	Clay.	Loss on Ignition.
0–14 in.	11.1%	19.4%	38.2%	13.2%	12.0%	10.7%	7.0%	trace	2.1
16–24	27.0	33.9	41.4	15.3	4.4	2.5	2.4	"	0.64
24–36	3.4	25.0	49.6	17.5	4.8	3.1	trace	"	0.45

Note should be taken of the high percent of the coarse gravel in the upper layers of the soil, and also the comparatively high percent of fine and very fine sand in the upper fourteen inches.

The real specific gravity of a typical sample and also the separates was determined. The results obtained are set forth in Table 2.

TABLE 2.—*Specific Gravity of a Typical Pumice Soil and of its Separates.*

Depth of Sample.	Real Specific Gravity.
0–16 in.	2.01
16–24	1.2
24–36	2.22

Separates.

Coarse gravel	
Fine gravel	1.1
Coarse sand	1.33
Medium sand	1.81
Fine sand	2.66
Very fine sand	2.85

The sample employed was sifted through a 2 mm. sieve.

An examination of the above data reveals that the real specific gravity of these soils is low, in comparison with normal soils. On the other hand when cognizance is taken of the vesicular nature of much of the soil mass this is not unusual.

Water Capacity.—The hygroscopic and capillary capacity of various samples of soil was also determined. A sample typical of the area was found to contain 2.7 percent of hygroscopic water. The maximum capillary water capacity was determined by saturating one fourth of a cubic foot of soil and reweighing it, after the free water had passed away. The following results were obtained, as shown in Table 3.

TABLE 3.—*Water Capacity of a Pumice Soil.*

Depth of Sample.	Maximum Capillary Water Capacity, Per Cent.	
0–16 in.	(*a*) by wt.	51.2
	(*b*) by volume	44.8
16–36 "	(*a*) by wt.	47.4
	(*b*) by volume	32.4

As is revealed by the above data, these soils have an extremely high so-called capillary water capacity. Although most soils, and especially is this true of the finer textured soils, under laboratory conditions have a higher water-retaining capacity than under field conditions, it is doubtful if these soils would have an appreciably lower capacity, since they are extremely loose and porous under natural conditions. Furthermore, precautions were taken to compact the soil before the water was added. When cognizance is taken that the average coarse sandy soil under identical conditions, in the laboratory, retains approximately twenty percent by weight of capillary water, it is readily seen that these pumice soils are very unusual in this respect.

Wilting Coefficient.[2]—It was considered of sufficient interest as well as of economic importance to determine the amount of water remaining in these soils when plants wilt. Galvanized iron containers, two inches in diameter and ten inches in depth were used. Wheat seed that had been soaked in running water twenty-four hours were placed in the soil, to which twenty percent of water had been added. The containers were sealed with a mixture of petrolatum and paraffin. The experiments were conducted in a laboratory, the temperature and relative humidity of which were not recorded. When permanent wilting had taken place, the moisture remaining in the soil was determined. The resultes obtained are given in Table 4.

[2] These studies were carried out by Messrs. H. A. Schoth and J. A. Martin.

TABLE 4.—*Wilting Coefficients and Available Water in a Pumice Soil.*

Depth of Sample.	Wilting Coefficient, Per Cent.	Available Water, Per Cent.
0–16 in.	(*a*) 9.69	41.80
	(*b*) 9.95	
16–24 "	(*a*) 9.10	38.05
	(*b*) 9.6	

The amount of available water that these soils are capable of holding is very high in comparison with most soils. On account of this property and the nature of the climate of this region, it is probable that one application of irrigation water during the growing season would suffice for most crops grown on these soils.

Mineralogical Study.—The minerals composing the various separates were determined by means of a petrographic microscope. There is present some pyroxene, olivene, quartz, magnetite and an occasional indeterminable particle. Quartz predominates in the finer separates and was found to be almost transparent. There is also more pyroxene, olivene and magnetite in the finer separates. Thus, there is present material derived from basic rock, on the one hand, and acidic rock on the other. This is probably the result of two or more vents occurring simultaneously, from one basic material being blown to pieces and deposited; from the other acidic material.

Soluble Salts.—The soluble salt content of certain of these soils was likewise determined. Two methods of procedure were adopted. In one case, the sample to be studied was saturated with distilled water and placed in the cup of an electric bridge and the resistance in ohms determined. In the other, one part of soil to five of distilled water was shaken three hours and let stand for twenty-four. The resistance of the soil extract was determined by means of the electric bridge. The results obtained appear in Table 5.

TABLE 5.—*Resistance in Ohms of Pumice Soil and Soil Extract.*

Depth of Sample.	Resistance of Pumice Soil.	Resistance of Extract.
0–16	7500 at 58° F	6300 at 66° F
16–24	6000 " " "	6500 " " "
24–36	4000 " " "	3800 " " "

An examination of the above data reveals that the total soluble salts in these soils is low. The subsoils apparently run higher in soluble material than the surface. This may be due, in part at least, to the leaching of some of the soluble material from the upper to the lower soil strata. As indicated previously, there is practically no run-off in this tillable area. The rain that falls is lost from the soil by percolation into the water table below or by evaporation from the surface. On account of the very porous nature of the soil, water falling upon it penetrates very readily.

Although the mineralogical make-up of these soils is somewhat indicative of their chemical composition, a chemical analysis, furnished by H. V. Tartar, of a sample that is representative of this area, is interesting and important economically.

N	.05
P_2O_5	.187
K_2O	2.82
CaO	3.39
MgO	2.33
Humus	.90

The results of this analysis show these soils to be abnormally high in potassium, calcium and magnesium. The available mineral plant food was not determined chemically. However, the results of the distilled water extract as given above, are more or less indicative of the soluble salt content.

Agricultural Outlook.—The future of agriculture in this area is problematical. Judging from the newness of the deposit, the very low water-soluble salts, the deficiency in humus and the results obtained by numerous settlers, there will be very little accomplished until the organic matter of these soils is materially increased. Furthermore it is probable that this will be difficult to accomplish until mineral fertilizers are added. In this connection, it is well to note that where brush heaps have been burned the native grasses, as well as rye, make much better growth.

PETROGRAPHY OF VARIOUS SOILS DERIVED FROM VOLCANIC EJECTA.

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In a general study of American soils now in progress in this Bureau it was considered advisable to examine certain soils of special natures not only for the sake of the information to be gained concerning them *per se,* but also for the light that such examinations might throw upon soils in which these special characteristics are not so pronounced.

Soils directly derived from volcanic ejecta are known to be common, although scattered; and the additions made to practically all soils by the fall of volcanic dust is not negligible and may be considerable,[1] even at great distances from the centers of volcanic activity. Certain soils of volcanic origin are noted for their fertility while, per contra, others appear barren. In the present work a number of soils in this Bureau's collection, definitely known to be volcanic ash or directly derived from lava, were examined petrographically; and the results are given herewith.

Available mechanical analyses are given in Table 1 and mineralogical analyses in Table 2. In connection with the mineralogical analyses it should be stated that only those minerals in large enough particles and fresh enough for determination are listed. This excludes all particles of clay dimensions and some few deeply weathered grains of larger size. In certain of the Hawaiian soils, the material was so coated with iron stains as to render the minerals indeterminable in that state. Where such was the case, a hydrochloric acid digestion was made for the purpose of clearing the material. Such digestions probably removed acid-soluble minerals as, for example, apatite; and consequently in the digested material only insoluble minerals would be found, except in cases where the soluble minerals were inclosed in insoluble material.

Data relating to the locality, color, and other characteristics of the soils studied are given in the following brief résumé.

TABLE 1.—*Mechanical Analysis of Soils derived from Volcanic Ejecta.*

(Analysis of No. 6832 is by F. O. Martin, and the remainder are by Ralph S. Hosmer.)

No.	Fine Gravel.	Coarse Sand.	Medium Sand.	Fine Sand.	Very Fine Sand.	Silt.	Fine Silt.	Clay.	Loss at 110° C., and on Ignition.
6832	0.18	0.54	0.30	2.40	1.38	93.86	......	1.24	0.23
3611	0.09	0.87	3.87	5.84	9.62	19.54	4.56	38.95	18.28
3612	1.07	1.87	7.49	8.01	22.12	17.79	5.48	21.30	15.83
3613	0.00	0.15	0.82	4.59	25.47	26.28	5.58	23.22	15.62
3614	0.93	0.91	1.40	2.98	7.82	18.10	6.75	45.55	16.47
3615	0.14	0.20	0.62	2.85	16.32	19.80	5.80	39.00	16.61
3616	2.74	3.56	3.04	3.55	9.23	14.90	5.77	41.43	15.54
3617	37.49	30.50	18.43	7.24	3.13	1.10	0.24	1.40	0.98
3618	8.36	9.17	13.65	9.42	18.03	10.16	3.14	16.30	12.80
3619	0.10	0.28	0.78	4.04	14.88	18.44	8.26	25.60	29.30
3620	0.09	0.33	0.88	8.83	31.12	13.05	3.90	8.38	34.10
3621	0.00	0.06	0.27	2.17	12.17	18.92	5.53	44.10	18.26
3622	0.03	0.15	0.61	6.44	27.33	15.28	3.18	8.80	39.86
3327	0.04	0.11	0.77	3.48	21.97	42.57	5.71	11.45	13.24

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[1] Free, E. E., Movement of soil material by wind; with bibliography of eolian geology, by S. C. Stuntz, U. S. Dept. Agric., Bur. of Soils, Bull. 68, p. 159, 1911.

TABLE 2.—*Mineralogical Analyses.*

Soil No.	Isotropic Material. *n* Low.	Isotropic Material. *n* Higher.	Quartz.	Mica.	Muscovite.	Biotite.	Amphibole.	Hornblende.	Pyroxene.	Augite.	Orthoclase.	Microcline.	Plagioclase.	Oligoclase-Albite.	Oligoclase.	Andesine.	Labradorite.	Anorthite.	Olivine.	Calcite.	Dolomite.	Apatite.	Hematite.	Magnetic Iron Ore.	Tourmaline.	Epidote.	Zircon.	Rutile.	Spherulites.	Remarks.
3979	o	...	o	...	o	o	...	o	...	...	o	...	o	...	...	...	...	...	...	...	...	o?	...	o	...	...	...	...	...	Mainly glass. Quartz fairly plentiful.
6832	o	...	o	...	o	o	o?	...	...	...	o	...	...	...	...	...	...	...	...	...	...	...	...	o	...	...	...	...	...	Mainly glass.
3611	o	...	o	...	...	...	...	...	...	o	...	...	...	...	...	...	...	...	o	...	...	...	...	o	...	...	...	...	...	Isotropic material and olivine predominant.
3612	o	...	o	...	...	o?	o?	...	...	o	...	...	...	...	...	...	...	...	o	o?	...	o	...	o	...	...	...	...	...	Isotropic material and olivine predominant.
3613	o	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	o	...	...	...	o	o	...	...	...	...	...	Olivine present in small amounts.
3614	o	...	o?	o?	...	...	o?	...	o?	...	...	...	...	...	...	...	...	...	...	o	o	...	...	o	...	...	...	...	...	Largely calcareous.
3615	o	...	...	...	...	o	o?	...	o?	...	...	...	o	...	...	...	...	...	o	...	...	...	...	o	...	...	...	...	...	Isotropic material and olivine predominant.
3616	o	o	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	o	...	...	o	o	o	...	...	...	...	o	Isotropic material and olivine predominant. Apatite as large, rare grains.
3617	o	o	...	...	...	...	...	...	...	o?	...	...	...	...	...	...	...	...	o	...	...	o?	...	o	...	...	...	...	o	Scoria.
3618	o	o	...	...	...	...	...	...	...	o	...	...	...	...	...	...	...	...	o	...	...	...	...	o	...	...	...	...	o	Isotropic material and olivine predominant.
3619	o	o	...	...	...	...	...	...	...	...	...	...	o	...	...	...	...	...	o	o	o	...	...	o	...	...	...	...	...	Isotropic material predominant.
3620	o	o	...	...	...	...	...	...	...	...	...	...	o	...	...	...	...	...	o	o	o	...	...	o	...	...	...	...	...	Isotropic material predominant.
3621	o	o	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	o?	...	o	o	...	...	...	...	...	Material very decomposed.

TABLE 2.—*Continued.*

Soil No.	Isotropic Material. n Low.	Isotropic Material. n Higher.	Quartz.	Mica.	Muscovite.	Biotite.	Amphibole.	Hornblende.	Pyroxene.	Augite.	Orthoclase.	Microcline.	Plagioclase.	Oligoclase-Albite.	Oligoclase.	Andesine.	Labradorite.	Anorthite.	Olivine.	Calcite.	Dolomite.	Apatite.	Hematite.	Magnetic Iron Ore.	Tourmaline.	Epidote.	Zircon.	Rutile.	Spherulites.	Remarks.
3622	O	O	...	...	...	...	...	...	...	...	...	...	O	...	...	...	O	...	O	...	O	...	...	O	...	...	...	...	...	Isotropic material, plagioclase, and olivine predominant.
1618	O	...	O	...	O	O	...	O	...	...	O	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	O	O	...	Mainly glass.
993	O	...	O	...	O	O	...	O	...	...	O?	...	...	...	O	O	O	...	...	...	...	O	...	O	O	O	...	...	...	Plagioclases, hornblende, and quartz predominant.
1022	O	...	O	...	O	O	...	O	...	...	...	...	O	O	...	O	O	...	...	...	...	...	...	O	...	...	...	O?	...	Plagioclases and hornblende predominant.
1023	O	...	O	...	O	O	...	O	...	O	O	...	...	...	O	O	O	...	...	...	...	...	...	O	...	...	...	...	...	Quartz, plagioclases, and hornblende predominant.
3326	O	...	O	...	O	O	...	O	...	...	...	...	...	...	O	O	O	...	...	...	...	...	...	O	...	...	...	...	...	Plagioclases and hornblende predominant.
3327	O	...	O	...	O	O	...	O	...	O	O	...	...	...	O	O	O	...	...	...	...	O?	...	O	O	...	...	...	...	Plagioclases and Isotropic material predominant.
3328	O	...	O	...	O	O	...	O	...	O	O	O	...	...	O	O	O	O	...	...	...	...	...	O	O	O	O	O	...	Quartz, plagioclase, and hornblende predominant.

O indicates the presence of the mineral. O? indicates that the mineral is probably present, but that the data obtainable were not sufficient to identify it beyond doubt. No tests were made to determine titanium in the magnetite.

No. 3979. Nebraska.[2] Mixed sample of volcanic ash from four miles west of Wauneta, Chase County, Wauneta Post Office, Chase County, Alma, Clay County, and Dawson County. Very light in color. Collected by E. H. Barbour, March, 1899.

No. 6832. Nebraska.[2] Frontier County. Volcanic ash. Very light in color. Collected by E. H. Barbour, July, 1902.

No. 3611. Hawaiian Islands. 0″–9″. From base of Punchbowl, a tuff-cone in Honolulu. Soil derived from the tuff. Brownish in color. Sent by A. B. Lyons, January, 1898.

No. 3612. Hawaiian Islands. 0″–9″. From a point east of Honolulu. Covered apparently with lava from an eruption of recent date, but possibly partly alluvial in origin. Color, dirty brown. Sent by A. B. Lyons, January, 1898.

No. 3613. Hawaiian Islands. 0″–9″. Telegraph Hill. From disintegration of the lava of this recent lava-cone. Color, bright hematitic red. Sent by A. B. Lyons, January, 1898.

No. 3614. Hawaiian Islands. 0″–9″. Clay from base of Rocky Hill, a recent lava cone. The soil (clay) appears to have been formed in the sea which was then at a level at least 60 feet higher than at present. Color, dark gray. Sent by A. B. Lyons, January, 1898.

No. 3615. Hawaiian Islands. 0″–9″. From slope, two miles east of Honolulu. Derived from ancient lava making up the main mass of the island. Color, dark brown. Sent by A. B. Lyons, January, 1898.

No. 3616. Hawaiian Islands. 0″–9″. From foot of slope, two miles west of Honolulu. Characteristic sample of red soil that predominates in drier parts of the older islands. This may not be free from admixture with material from later lava. Sent by A. B. Lyons, January, 1898.

No. 3617. Hawaiian Islands. 0″–9″. Scoria (lapilli) scattered over all the region where Honolulu now stands. These gravel beds are from 2 to 20 feet thick on the plain, consisting of lava fragments looking as fresh as the lava of Kilauea. The superficial portion is more or less decomposed, forming the gravelly soil of Honolulu. Basaltic appearance. Sent by A. B. Lyons, January, 1898.

No. 3618. Hawaiian Islands. 0″–9″. Formed from the lapilli of No. 3617, and taken from same spot. Sample taken from a point more than 100 feet above present sea level, but may have been submerged for a time. Color, brownish. Sent by A. B. Lyons, January, 1898.

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[2] The occurrence of similar ash has been noted by Salisbury, R. D., Volcanic ash in southwestern Nebraska, Science, n. s., 4: 816–817, 1896.

No. 3619. Hawaiian Islands. 0″–9″. From Waimea, at foot of the rather old Kohala Mountain. Soil apparently formed from volcanic ash thrown from the numerous neighboring craters. Soil comes probably from a garden that has been cultivated without fertilizers for 50 years. Color, light dirty brown. Sent by A. B. Lyons, January, 1898.

No. 3620. Hawaiian Islands. 0″–9″. From a point not very distant from No. 3619, but a virgin soil. Color, light dirty brown. Sent by A. B. Lyons, January, 1898.

No. 3621. Hawaiian Islands. 0″–9″. From same region as No. 3616,—two miles west of Honolulu—but from some distance up the slope. Color, hematitic red. Sent by A. B. Lyons, January, 1898.

No. 3622. Hawaiian Islands. 0″–9″. From glen in Kohala Mountain, at Waimea. Probably mainly derived from the original lava of the mountain. Possibly Nos. 3619 and 3620 have same origin and have been caried down to the plain by agency of water. Color, dirty brown. Sent by A. B. Lyons, January, 1898.

No. 1618. Kansas,[3] McPherson County. Volcanic dust. Subsoil. Color, very light. J. A. Udden, Collector.

No. 993. Washington, Walla Walla County. Two miles west of Walla Walla. Soil 10–20 feet. No subsoil. Color, light brown. Bunch grass, fruit, wheat. Volcanic ash. Collected by J. M. Blain, October 28, 1892.

No. 1022. Washington, North Yakima, Yakima County. No subsoil; soil is unchanged down to coarse gravel. Soil 36–120 in. Basaltic ash. Color, light brown. Sage brush, fruit, vegetables, grain. Collected by J. M. Blain, November 3, 1892.

No. 1023. Washington. Ellensburg, Kittitas County. Volcanic ash. Color, grayish. Soil 60–120 in. Bunch grass, sage brush, hay, fruit, grain. Collected by J. M. Blain, November 4, 1892.

No. 3326. Washington, North Yakima, Yakima County. Trace of black and white alkali. Volcanic ash. Color, light brown. Soil 0″–12″. Wheat, hops, fruit. Collected by Milton Whitney, September, 1897.

No. 3327. Washington, North Yakima, Yakima County. Trace of black and white alkali. Volcanic ash. Subsoil 12″–36″. Color, light grayish brown. Wheat, hops, fruit. Collected by Milton Whitney, September, 1897.

No. 3328. Washington, North Yakima, Yakima County. Volcanic ash. Color, light brown. Soil 0″–12″. Wheat, hops, fruit. Collected by Milton Whitney, September, 1897.

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[3] See Chamberlin and Salisbury, Geology, Vol. I, 22, 1904.

Table 2 shows that isotropic material with a rather low refractive index is the only substance occurring in all the soils. This was to be expected since volcanic ejecta often consists largely of glassy material, although it is possible that some of the isotropic material noted above is not of glassy nature. The presence of volcanic glass in a soil may, in general, be taken as a criterion of the origin of the soil, though, of course, account must be taken of the probability of admixture with material from other sources. The differentiation of glass of volcanic origin from glass derived from broken bottles and similar sources is not always possible; and in the application of the above mentioned criterion great care and, if possible, the examination of several samples of the same soil type from different localities are necessary.

Samples Nos. 3979, 6832, and 1618 are all of a very silicious character and show a mineral composition in agreement with such a character. They all consist mainly of the isotropic material of low refractive index, with the other substances listed occurring in minor quantities. The main differences between the three samples are the occurrence of doubtful amphibole in sample No. 6832, the absence of hornblende from the same, although it is very probable that the doubtful amphibole is hornblende, a probability which removes both of the above differences, the occurrence of plagioclase in sample No. 3979, the occurrence of doubtful apatite in the same, the absence of magnetite from sample No. 1618, and the occurrence of zircon and rutile in the same. None of these differences are fundamental.

The Hawaiian soils, samples Nos. 3611–3622, inclusive, are all fairly similar with the exception of samples Nos. 3614, 3619 and 3620, these three latter showing a sufficient amount of calcareous material to sharply differentiate them from the others. Speaking generally, it may be said that these soils are characterized by the total absence or presence of a very minute quantity of quartz, the presence of isotropic material of rather high refractive index, and the presence of olivine, often in comparatively large amounts.

The Washington soils present a rather great variety of mineral species, and are characterized especially by the large amount of well developed lime-soda feldspars present.

SUMMARY.

1. Soils derived mainly from volcanic ejecta can be recognized generally by the presence of glass particles, when such particles occur in noticeable quantity.

2. From the data here presented, it appears that the soils examined fall into three general classes: (*a*) Very silicious soils containing large proportions of isotropic material of low refractive index and associated with comparatively large proportions of quartz. Illustrations are furnished by the samples from Nebraska and Kansas. (*b*) Soils containing isotropic material of higher refractive index, relatively large proportions of olivine, and little or no quartz. Examples are the Hawaiian soils. (*c*) Soils characterized by the relatively larger number of mineral species readily recognized, and especially by the occurrence of well-developed lime-soda feldspars. Examples are the samples from Washington.

3. The presence of relatively large proportions of glasses in certain soils derived mainly from volcanic ejecta, owing to the chemical characteristics of glasses in general, suggests that, with such soils, the inorganic soil material would be more readily and quickly modified than with soils of other origin.

A STATISTICAL STUDY OF BARLEY AT THE DICKINSON (N. D.) SUBSTATION.[1]

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(*Presented at the special Great Plains meeting, Hays, Kansas, July 8–10, 1914.*)

Introduction.

In making a study of barley it is necessary to arrange the many existing varieties in groups or sub-groups. Few cereal crops have as many distinct botanical groups as has barley. This has been beneficial in giving wide adaptability to the crop as a whole. Certain groups of barley have been found better adapted to some localities than to others. It is the custom of experimenters to point out the advantage of a certain group of barley best adapted to their locality and to recommend to farmers of that section the growing of the same. For example, Shepperd and Churchill,[2] from experiments conducted at Fargo, North Dakota, have pointed out that six-row hulled barleys lead in yield and are best adapted to the conditions at that place. The two-row hulled varieties ranked next in order of yield and the naked (hull-less) varieties produced the lowest yield. Atkinson[3] has shown, from experiments conducted at Bozeman, Mont., that naked barleys of different groups produce a higher yield of grain in that section than the other types and that the two-rowed hulled barley is a higher yielder than the six-rowed hulled. At the Dickinson substation, located in the southwestern part of North Dakota, about midway between the above-mentioned stations, it has been found that the two-rowed hulled barleys yield better than either the six-row hulled or six-row naked types, and the growing of the leading two-row varieties has been recommended[4] to farmers of western North Dakota.

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[1] The experiments which resulted in the data discussed herein are cooperative between the Office of Cereal Investigations, U. S. Department of Agriculture, and the N. D. Experiment Station.

[2] Shepperd, J. H. and Churchill, O. O., Cereal Crop Experiments, N. Dak. Expt. Sta. Bul. 75: 328, 1907.

It is the purpose of this paper to present some of the data which have been collected at the Dickinson substation showing the differences that have been found between the two-row hulled nodding bearded, the six-row hulled bearded and the six-row naked hooded groups of barley.

Nature of the Experiments.

In all the varietal tests at Dickinson one of the principal objects has been to determine the relative yielding power of the different varieties. Efforts have been made also to find reasons for the existing variation in yields between different groups of varieties of the same cereal. In order to make these studies complete the work is divided into plat and nursery experiments. The plat experiments are designed to conform as nearly as possible to the best practical method of farm practice in the northern Great Plains area. In these plats the crops are studied on an extensive scale. In the nursery tests, which are confined to short rows, the crops are studied intensively. The rows are uniformly spaced and a weighed quantity of seed is planted in each row. This method makes possible the testing of a large number of varieties and offers a means of making a study of a considerable number of plants of each variety.

In order to compare the three groups of barley some of the data obtained from both the plat and nursery experiments are given here.

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[3] Atkinson, Alfred, Grain Investigations with Wheat, Oats, and Barley, Mont. Expt. Sta. Bul. 84: 228, 1911.

[4] Waldron, L. R., Annual Reports of the Dickinson Substation, 1–6, 1908–1913. Clark, J. A., Cereal Experiments at Dickinson, N. Dak., U. S. Dept. of Agr., Dept. Bul. 33 (in press).

Results from Plat Experiments.

In Table 1 are given the annual and average yields obtained from three varieties of barley: Hanna, C. I. No. 203, representing the two-row hulled group; Manchuria, C. I. No. 863, representing the six-row hulled group; and Nepal, C. I. No. 262, representing the six-row naked hooded group, for the eight-year period, 1906–1913, inclusive.

Table 1.—*Annual and Average Yield of Three Varieties of Barley, Grown at Dickinson, N. Dak., for the Eight Years, 1906 to 1913.*

C. I.[1] No.	Group and Variety.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	Average.
	Two-row hulled									
203	Hanna..........	28.9	46.8	28.5	39.8	34.8	17.0	46.0	31.4	34.2
	Six-row hulled									
863	Manchuria.......	27.6	16.5[2]	27.9	30.2	28.0	7.8	40.3[3]	30.6	26.1
	Six-row naked[4]									
262	Nepal...........	31.3	40.9	22.1	24.1	23.0	8.4	34.6[3]	20.9	25.6

[1] Cereal Investigations number.

[2] Damaged by wind.

[3] Computed from the yield of Hanna.

[4] For purposes of comparison the yield of this naked barley is given in bushels of 48 pounds, although the actual weight is 60 pounds to the bushel.

These varieties were selected because they had been grown for the longest period of years. Had the highest-yielding varieties been shown, the Hannchen variety would have represented the two-row group and the Gatami, the six-row group. The Nepal variety, C. I. No. 262, is the only variety of that group which has been grown in plat tests for several years. The varieties given, however, are standard varieties for their respective groups. The two-row variety out-yielded the six-row variety in all years and the naked variety in all years but one, 1906. It had an average yield of 34.2 bushels compared with 26.1 bushels for the six-row variety, a difference of 8.1 bushels, or 32 percent. The naked variety gave an average yield of 25.6 bushels, which was slightly less than that of the six-row variety. It was exceeded in yield by the two-row variety by 8.6 bushels, or 33.5 percent, and by the six-row variety by .5 of a bushel, or 4 percent. In these comparisons the yield of the naked barley is computed at 48 pounds instead of 60 pounds, its standard weight. Since the naked barley is solid grain without hulls, a further allowance of from 7 to 10 percent probably should be made in order that the comparison be entirely fair to this variety.

If it be assumed that the varieties shown in the table are fairly representative of their groups, there should remain no doubt as to the superior yielding of the two-row hulled over the six-row hulled or the six-row naked hooded varieties at Dickinson.

These data, as well as those from other varieties grown for shorter periods of years, when the differences shown would be still greater, have formed the basis for recommending the growing of two-row varieties in western North Dakota. In order to further substantiate this evidence obtained from the field plats the writer has attempted a statistical study of some of the data obtained in the nursery trials where each group is represented by a considerable number of comparable varieties.

RESULTS FROM NURSERY EXPERIMENTS.

In the nursery as well as in plat tests it is desired to determine the relative yielding power of the different varieties but here an effort is made also to find reasons for the existing variation in yields between different groups of varieties if not between the varieties themselves. In connection with the yield, therefore, some data are presented on a few of the plant characters that materially affect the yield. In working up the data, recourse has been had, to a limited extent, to biometric methods in using the "probable error" as a test of the probable validity of conclusions. The "probable error" of the mean merely indicates that had the test been repeated the chances are even that the true mean would be somewhere between the limits of the mean given with its probable error added or subtracted. The differences between the groups with their probable error are also shown.

It has been pointed out by Pearl and others that when the mean of each of two comparable series has been determined and the means differ by a certain amount, say three times as great as the probable error, one mean is said to be significantly greater than the other. When the difference is three times the probable error it has been found that the probability of the occurrence of a deviation as great or greater than this is 4.3 percent. This indicates that in every 100 trials a deviation of this size or greater would be expected to occur 4.3 times as a result of chance alone. When the deviation divided by the probable error equals 1, a deviation as large as the probable error is as likely to occur as not, and vice versa, when it passes 3 the odds against the deviation being due to chance, increase rapidly. For instance, when the difference is 8 times greater than the probable error there is only one chance in 1,470,588,234, or beyond any real power of conception, that the difference noted is due only to errors which would have occurred even if the varieties were exactly the same.

The data on yield include the yield of both grain and straw together with the percentage of grain in the plant (excluding roots). The data which have been collected on the plant characters are height of plant, number of heads per plant, length of heads, and the duration of the growing period, or the time between emergence and maturity. The complete data for all of the varieties for all the years are given in Tables 2 to 8 inclusive. In order to summarize the data a series of figures have been prepared showing graphically the mean data for the different groups and the probable error of the mean. The figures also show the differences between the groups with the probable errors of the difference. This shows the direct proportion of the probable error to the difference between the groups and aids in determining whether the differences found are large enough to be significant.

AVERAGE YIELDS OF GRAIN.

In Table 2 are given the annual yields of 27 varieties of barley for the five-year period, 1909–1913. Each of the three groups of barley under discussion is represented by nine varieties. It will be noted that the two-row varieties outyielded the six-row varieties in all years except 1910, when six of the nine two-row varieties were damaged by hail. The damage to these varieties was without doubt the cause of their low average yield for that year. During all the years in which they were grown the yield of the two-row varieties exceeded that of the naked varieties. The average yield of the six-row varieties was greater than that of the naked varieties in three of the five years.

It has been shown in Table 2 that these groups, each composed of nine varieties, are comparable except that part of the varieties in the two-row group were damaged by hail in 1910 and its yield, therefore, was somewhat reduced. The groups here occupy the same rank as they did in the field plats recorded in Table 1 where each group was represented by only one variety. The differences in yield between the groups also are in about the same proportion. The question whether these differences are great enough to be of any importance can be determined here by comparing them with their probable error.

In Fig. 12 is shown the mean yield of grain, for the three groups, during the five-year period, together with the differences in yield between the groups. The probable error for these mean yields and for their differences is also given. It will be seen that the mean yield of the two-row hulled group of barley equals 296.2 ± 7.4 grams and the next highest yielding group, the six-row hulled barleys, has a mean yield of 207.1 ± 5.7 grams. The naked group has the lowest yield, 204.7 grams with a probable error of 5.1 grams.

Table 2.—*Annual and Mean Yield and Probable Error in Yield of Grain from 17-foot Rows of 27 Varieties and Strains of Barley Grown at the Dickinson (N. Dak.) Substation for the 5-Year Period, 1909 to 1913.*

C.I. No.	Group and Variety.	Yield of Grain in Grams per Row.					
		1909.	1910.	1911.	1912[1].	1913.	Mean and P. E.
	Two-row hulled						
531	Hannchen[2]	277.5	195.5[3]	348.3	460.4	393.9	335.1
681	Hanna No. 1	275.1[4]	67.5[3]	340.0	590.0	388.5	332.2
625	Princess	272.6[4]	145.0[3]	290.0	535.0	403.5	329.2
658	White Smyrna (Ouchac)	266.7[4]	319.0	365.0	315.0	345.0	322.1
530	Chevalier II	356.0	207.1[3]	225.0	275.0	450.0	302.6
637	World Champion	206.0	191.5[3]	130.0	365.0	438.0	266.1
189	Kitzing	263.0	108.3[3]	200.0	292.5	460.0	264.8
158	Bavarian	271.0	263.6	255.0	177.5	339.0	261.2
207	Lower Frankish	303.0	247.5	220.0	150.0	342.0	252.5
	Six-row hulled						
537	Oderbrucker	260.0	249.8	130.0	165.0	388.0	238.5
170	Manchuria	187.5[4]	287.0	180.0	170.0	308.0	226.5
626	California	114.0	263.5	240.0	245.0	250.0	222.5
171	Surprise	177.0	263.4	245.0	100.0	309.0	218.9
889	Reed Triumph	169.0	246.6	145.0	245.0	242.5	209.6
182	Odessa	204.0	207.5	175.0	175.0	270.5	206.2
205	Yenidje	247.0	213.8	180.0	150.0	241.0	206.2
575	Gatami	217.0	223.2	100.0	75.0	224.0	167.8
575–1	White Gatami	142.0	260.0	102.5	105.0	229.0	167.7
	Six-row naked						
489	Nepal (White hull-less)	198.2[4]	139.7[4]	280.0	290.0	296.5	240.9
533	" (Boehme ")	169.5	202.0	260.0	300.0	265.5	239.2
262	" (Myer ")	92.5	221.3	220.0	225.0	335.0	218.1
250	" (White ")	98.0	203.8	205.0	275.0	268.5	208.1
247	" (" ")	170.0	201.0	147.5	225.0	262.5	201.2
22	" (" ")	100.0	187.9	195.0	265.0	243.5	198.3
475	" (Colorado ")	100.0	236.3	190.0	185.0	265.5	195.4
595	" (White ")	100.0	156.6	220.0	205.0	221.0	180.5
598	" (" ")	84.0	149.8	165.0	145.0	261.5	161.1
	Mean of three groups						
	Two-row hulled	276.8	194.0	262.7	351.2	395.5	296.2 ± 7.4
	Six-row hulled	190.8	246.1	166.4	159.0	273.5	207.1 ± 5.7
	" " naked	123.6	188.7	209.3	235.0	268.8	204.7 ± 5.1

[1] Yields from a second-growth crop, the first growth having been destroyed by hail on July 11.

[2] Yields given represent an average of about 33 rows which were used as checks.

[3] Damaged by hail.

[4] Yield data missing and data given computed on the basis of the relative yields of this variety and the check in the succeeding years.

A comparison of the two-row hulled and the six-row hulled groups show a difference of 89.1, with a probable error of 9.2 grams, in favor of the former. This difference of over nine times its probable error can be said certainly to be significant. A comparison of the two-row group and the naked group shows the difference to be over ten times its probable error. This would indicate that differences in yield found between the two-row hulled group, on the one hand, and the six-row hulled and the naked groups, on the other, is due to the inherent character of the varieties rather than to error, as the chance that the differences were due to error is so small that it is beyond any real power of conception. A comparison of the six-row hulled and six-row naked groups, however, shows a difference of only 2.4 grams with a probable error of 7.4 grams. Here the probable error is greater than the difference and indicates that the difference in yield between the two groups is within the limits of error and had the series been repeated the naked group might have produced the larger yield. Therefore, the difference in yield between these groups of six-row hulled varieties and six-row naked varieties of barley at Dickinson is of no significance.

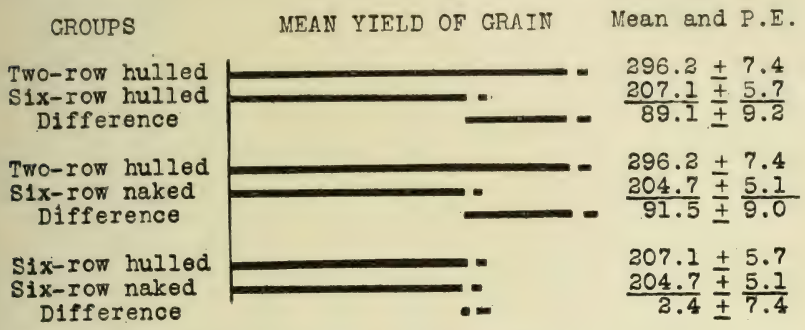

FIG. 12.—Mean yields of grain in 3 groups of barley, for the 5-year period, 1909–1913, with their differences in yield and the probable error of the yield and of the difference for each pair, shown graphically and in numerals.

AVERAGE YIELDS OF STRAW.

In connection with the yield of grain the yield of straw is a factor worthy of consideration. These data are given in Table 3 for the five-year period, for the twenty-seven varieties. The probable error for the mean yield of each group is also given.

Table 3 shows that the varieties giving the highest average yields of grain are not the varieties producing the highest yields of straw. The second-growth crop which developed after the hail in 1912 produced an abnormal yield of straw in some of the varieties. Each year the two-row group has given the highest average yield. The six-row hulled group produced a greater yield during three of the five years

TABLE 3.—*Annual and Mean Yields and Probable Error in Yield of Straw from 17-foot Rows of 27 Varieties and Strains of Barley Grown at the Dickinson (N. Dak.) Substation for the 5-Year Period, 1909 to 1913.*

C. I. No.	Group and Variety.	Yield of Straw in Grams Per Row.					
		1909.	1910.	1911.	1912[1].	1913.	Mean and P. E.
	Two-row hulled						
531	Hannchen[2]	618	341[3]	564	903	522	589.5
681	Hanna No. 1	610[4]	138[3]	573	990	467	555.4
625	Princess	612[4]	317[3]	365	865	590	549.8
658	White Smyrna (Ouchac)	540[4]	414	660	710	382	541.2
530	Chevalier II	660	533[3]	415	1090	655	670.6
637	World Champion	587	526[3]	400	1590	778	756.3
189	Kitzing	644	453[3]	468	473	745	556.3
158	Bavarian	603	456	490	757	486	558.5
207	Lower Frankish	742	503	587	635	535	600.4
	Six-row hulled						
537	Oderbrucker	978	309	315	350	854	561.2
170	Manchuria	534[4]	420	375	350	499	435.6
626	California	308	369[4]	355	365	298	339.1
171	Surprise	277	315	355	228	391	331.1
889	Reed Triumph	676	346	215	615	405	451.4
182	Odessa	348	388	305	275	380	339.0
205	Yenidje	605	399	315	465	298	416.4
575	Gatami	386	418	570	165	301	367.9
575-1	White Gatami	204	360	212	205	346	265.5
	Six-row naked						
489	Nepal (White hull-less)	500[4]	261[4]	510	690	437	479.6
533	“ (Boehme “)	508	286	405	590	301	418.0
262	“ (Myer “)	226	389	335	525	467	388.4
250	“ (White “)	256	390	375	525	333	375.8
247	“ (“ “)	460	394	332	450	334	394.1
22	“ (“ “)	234	357	330	530	460	382.2
475	“ (Colorado “)	257	391	495	390	358	378.1
595	“ (White “)	335	337	500	665	437	454.9
598	“ (“ “)	196	300	395	520	266	335.4
	Mean of three groups						
	Two-row hulled	624	409	502	890	573	597.6 ± 10.5
	Six-row hulled	479	369	335	335	419	389.7 ± 18.2
	“ “ naked	330	347	409	543	377	400.7 ± 9.3

[1] Yields from a second-growth crop, the first growth having been destroyed by hail on July 11.

[2] Yields given represent an average of about 33 rows which were used as checks.

[3] Damaged by hail.

[4] Yield data missing and data given computed on the basis of the relative yields of this variety and the check in the succeeding years.

than did the six-row naked group. The mean yield of straw for the three groups shows that the two-row hulled varieties produce considerably more straw than either of the other two groups. The straw yield of the six-row hulled group and the six-row naked group is nearly the same, the slight difference being in favor of the naked group. This is the reverse of their rank in yield of grain.

The mean yield and its probable error for the three groups, together with their differences and the probable error of the differences are shown in Fig. 13. Here it is seen that the difference in yield of straw between the two-row hulled group and the six-row naked group is 196.9 ± 14 grams. This difference of over 14 times its probable error is certainly significant, as is also the difference between the two-row hulled and the six-row hulled group, where it is nearly 10 times its probable error. The difference of only 11 grams with a probable error of 20.4 grams, between the six-row naked and hulled groups, is of no significance.

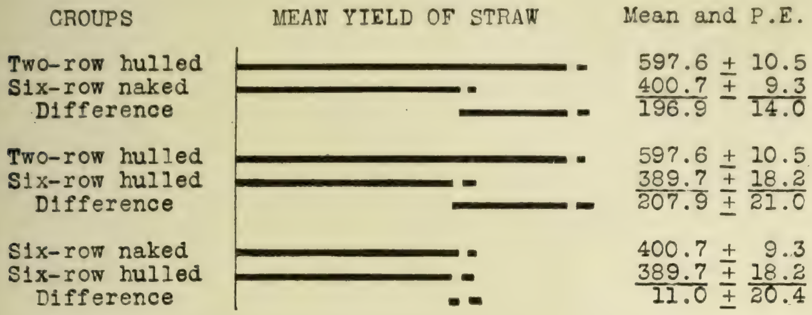

FIG. 13.—Mean yields of straw in 3 groups of barley, for the 5-year period, 1909–1913, with their differences in yield and the probable error of the yield and of the difference for each pair, shown graphically and in numerals.

PERCENTAGE OF GRAIN IN PLANTS.

Since barley straw is usually burned in the Great Plains area there is an advantage in growing barleys having a high percentage of grain. The percentage of grain in the plants (excluding roots) for the 27 varieties and strains representing the three groups for the five-year period, 1909 to 1913, is given in Table 4.

The table shows that the earliest maturing varieties have the highest percentage of grain. The mean percentages for the three groups during the series of years show no consistent differences. In the five-year mean, the six-row hulled group leads with 36 ± .7 percent of grain. The two-row hulled group is next with 34.1 ± .7 percent grain. The six-row naked group has the lowest percentage of grain, 33.7 ± .4. The differences between these groups are shown in Fig. 14.

TABLE 4.—*Annual and Mean Percentage of Grain and Probable Error of the Mean, in Plants (Excluding Roots) of 27 Varieties and Strains of Barley Grown at the Dickinson (N. Dak.) Substation for the 5-Year Period, 1909 to 1913.*

C. I. No.	Group and Variety.	Average Percentage of Grain in Plant.					
		1909.	1910.	1911.	1912.	1913.	Mean and P. E.
	Two-row hulled						
531	Hannchen	31.0	36.4	38.2	33.8	43.0	36.5
681	Hanna No. 1	31.1	33.2	37.2	37.3	44.9	36.7
625	Princess	30.8	27.7	44.3	38.2	40.6	36.3
658	White Smyrna (Ouchac)	33.1	46.1	35.6	30.7	47.5	38.6
530	Chevalier II	35.0	37.6	35.2	20.1	40.7	33.7
637	World Champion	26.0	34.5	24.5	18.7	35.7	27.9
189	Kitzing	29.0	22.8	30.0	38.6	38.2	31.7
158	Bavarian	31.0	44.6	34.0	19.0	41.1	33.9
207	Lower Frankish	29.0	38.6	31.1	19.1	39.0	31.3
	Six-row hulled						
537	Oderbrucker	21.0	41.2	29.2	32.0	31.2	30.9
170	Manchuria	26.0	43.4	32.4	32.7	38.2	34.5
626	California	27.0	44.1	40.3	40.2	45.5	39.4
171	Surprise	39.0	40.9	40.8	30.5	42.8	38.8
889	Reed Triumph	20.0	39.4	40.2	27.5	37.5	32.9
182	Odessa	37.0	37.3	36.4	38.9	44.1	38.7
205	Yenidje	29.0	43.2	36.4	24.4	44.7	35.5
575	Gatami	36.0	42.4	14.9	31.2	43.7	33.6
575–1	White Gatami	41.0	46.4	32.5	32.8	46.3	39.8
	Six-row naked						
489	Nepal (White hull-less)	28.4	34.9	35.4	29.6	40.4	33.7
533	" (Boehme ")	25.0	35.5	39.1	33.7	46.9	36.0
262	" (Myer ")	29.0	36.2	29.6	30.0	41.8	33.3
250	" (White ")	27.0	36.7	35.3	34.4	44.7	35.4
247	" (" ")	27.0	35.4	30.8	28.1	44.0	33.1
22	" (" ")	30.0	33.2	37.2	33.3	34.6	33.7
475	" (Colorado ")	28.0	40.4	32.5	32.2	42.5	35.1
595	" (White ")	23.0	41.0	30.6	23.5	33.6	30.3
598	" (" ")	30.0	37.8	29.4	21.8	49.5	33.7
	Mean of three groups						
	Two-row hulled	30.7	35.7	34.5	28.4	41.2	34.1 ± .7
	Six-row hulled	30.7	42.0	33.7	32.2	41.6	36.0 ± .7
	Six-row naked	27.4	36.8	33.3	30.6	42.0	33.7 ± .4

Fig. 14 shows a difference of 1.9, with a probable error of 1 percent between the six-row hulled and the two-row hulled groups. This difference of less than twice its probable error is of no significance. The difference of .4 ± .8 percent between the two-row hulled and the six-row naked group also is of no significance. A greater difference exists between the six-row hulled and the naked groups. However, this difference of 2.3 ± .8 percent, which is less than three times its probable error, is hardly large enough to be called significant. From the data given there appears to be little or no advantage for any one of the three groups in regard to the percentage of grain.

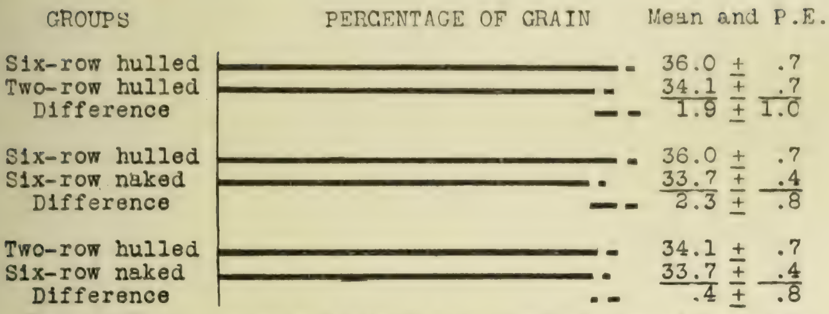

FIG. 14.—Mean percentage of grain in plants (excluding roots) in 3 groups of barley, for the 5-year period, 1909–1913, with their differences in percentage and the probable error of the percentage and of the difference for each pair, shown graphically and in numerals.

YIELD FACTORS.

The yield data which have been given merely show the results that have been obtained from growing two-row hulled, six-row hulled and six-row naked barleys at Dickinson. No reasons have been given to account for these yields, which, as shown in the introduction of this article, do not agree with the results obtained at other places. The question then naturally arises: Why do two-row hulled barleys yield best at Dickinson and why is there little or no difference in yield between the six-row hulled and the six-row naked groups? Data collected on a few of the plant characters and the duration of growth may help to explain this point.

HEIGHT OF PLANTS.

The height of plant has been correlated with high yield in the case of some cereals at certain places. It was possible, therefore, that this character might be a determining yield factor. Table 5 shows the annual and mean height of plants in the three groups, composed of 27 varieties, for the five years, 1909 to 1913.

The method of obtaining these data, as well as those on the number of heads per plant and the length of head, was to pull a portion of the row at harvest time and to take counts and measurements on 25 plants from each variety. The measurements upon height were taken from the base of the plant to the tip of the head, the awns not being measured. In 1912, because of the abnormal conditions resulting from the hail, the data on height of plant and length of head were taken in the field by means of measurements at several places in the row. The measurements for each year, therefore, are an average of

TABLE 5.—*Annual and Mean Height of Plants and Probable Error of Height of 27 Varieties and Strains of Barley Grown at the Dickinson (N. Dak.) Substation for the 5-Year Period, 1909 to 1913.*

C. I. No.	Group and Variety.	Average Height of Plant in Inches.					
		1909.	1910.	1911.	1912.	1913.	Mean and P. E
	Two-row hulled						
531	Hannchen	34.3	22.1	24.0	22.3	25.6	25.7
681	Hanna No. 1	36.2[1]	24.0	25.0	25.0	25.2	27.1
625	Princess	35.2[1]	23.0	20.2	26.0	27.4	26.4
658	White Smyrna (Ouchac)	31.8[1]	21.1	23.4	21.0	21.8	23.8
530	Chevalier II	36.8	22.9	25.2	28.0	26.2	27.8
637	World Champion	38.6	22.8	18.5	31.0	29.0	28.0
189	Kitzing	34.0	18.7	21.4	18.0	25.6	23.5
158	Bavarian	38.0	21.4	22.2	20.0	26.1	25.5
207	Lower Frankish	36.0	22.1	23.2	17.0	25.7	24.8
	Six-row hulled						
537	Oderbrucker	36.1	22.3	23.8	20.0	30.2	26.5
170	Manchuria	32.8	25.7	24.0	17.0	31.8	26.3
626	California	31.0	20.1	19.2	20.0	21.3	22.3
171	Surprise	30.8	23.8	22.6	18.0	28.4	24.7
889	Reed Triumph	39.9	20.1	19.8	25.0	25.1	26.0
182	Odessa	32.6	24.8	24.3	19.0	27.2	25.6
205	Yenidje	29.0	22.2	24.2	18.0	23.5	23.4
575	Gatami	31.1	21.5	16.1	22.0	23.8	22.9
575-1	White Gatami	30.4	23.2	21.9	18.0	23.3	23.4
	Six-row naked						
489	Nepal (White hull-less)	31.5[1]	27.2[1]	29.0	26.0	28.6	28.5
533	" (Boehme ")	30.0	22.8	26.4	23.0	30.4	26.5
262	" (Myer ")	35.0	25.7[1]	24.9	25.0	28.9	27.9
250	" (White ")	38.4	24.6	25.7	24.0	28.4	28.2
247	" (" ")	37.9	24.7	25.8	24.0	29.7	28.4
22	" (" ")	35.0	25.0	24.1	26.0	28.3	27.7
475	" (Colorado ")	32.4	22.5	26.6	23.0	29.6	28.8
595	" (White ")	31.2	23.4	28.7	25.0	28.9	27.5
598	" (" ")	26.8	23.2	24.5	23.0	29.0	25.3
	Mean of three groups						
	Two-row hulled	35.6	22.0	22.6	23.1	25.8	25.8 ±.4
	Six-row hulled	32.6	22.6	21.4	19.7	26.1	24.6 ±.3
	Six-row naked	33.1	23.2	26.2	24.3	29.1	27.6 ±.3

[1] Computed.

25 determinations, except in 1912, when they represent from 3 to 6 determinations. Therefore, the five-year mean for each variety is an average of over 100 measurements and for each group an average of over 900 measurements. This number of measurements should be sufficient to insure fairly accurate means.

Table 5 shows that the six-row naked group has the greatest average height for all years except 1909. In three of the five years the six-row hulled group is shortest. The mean for the three groups for the five-year period shows that the six-row naked group is tallest, with a height of 27.6 ± .3 inches. The differences between these groups are shown in Fig. 15.

Fig. 15 shows that there is a difference in height of 1.8 ± .5 inches between the six-row naked and the two-row hulled groups. This difference is large enough to be of significance, as also is the difference of 3 ± .4 inches between the six-row naked and six-row hulled groups. Between the two-row and six-row hulled groups, the difference of 1.2 ± .5 inches is hardly significant. From the data given it would appear that the height of the plants is not a factor in determining yield.

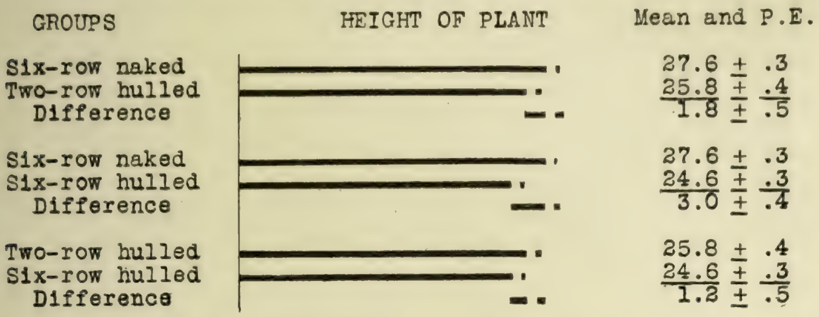

FIG. 15.—Mean height of plant in 3 groups of barley, for the 5-year period, 1909–1913, with their differences in height and the probable error of the height and of the difference for each pair, shown graphically and in numerals.

HEADS PER PLANT.

The number of heads which each plant produces or, in other words, the tillering or stooling of the plants, is an important factor. During four years, data were taken on the number of heads per plant in the 27 varieties and strains of barley under discussion. The data were not taken in 1912, as the tillering of the second-growth crop was not normal. During three of the five years, data were taken on the number of culms per plant. These data agree very closely with the data on heads per plant but as the former data are for a shorter period, and therefore not comparable, they are not included here.

Table 6 shows the annual and mean number of heads per plant for the four years, 1909 to 1911 and 1913. The table shows that the two-row varieties produce a larger number of heads per plant than is usual among the varieties of the other two groups. In 1911, a very dry year, there was but very little tillering and very few plants of any of the varieties produced more than one head. With the exception of this year, the two-row group produced on an average a

TABLE 6.—*Annual and Mean Number of Heads per Plant and Probable Error of the Mean of 27 Varieties and Strains of Barley grown at the Dickinson (N. Dak.) Substation for the 4 Years, 1909 to 1911 and 1913.*

C. I. No.	Group and Variety.	Average Number of Heads per Plant.				
		1909.	1910.	1911.	1913.	Mean and P. E
	Two-row hulled					
531	Hannchen	5.0	2.3	1.2	3.9	3.10
681	Hanna No. 1	4.9[1]	2.6	1.3	3.4	3.05
625	Princess	4.1[1]	2.3	1.0	4.1	2.88
658	White Smyrna (Ouchac)	6.3[1]	3.3	1.4	4.5	3.88
530	Chevalier II	4.1	2.4	1.1	3.1	2.68
637	World Champion	3.4	2.1	1.0	3.2	2.18
189	Kitzing	4.8	2.3	1.1	5.3	3.38
158	Bavarian	4.7	1.9	1.0	3.1	2.68
207	Lower Frankish	5.1	2.5	1.2	2.7	2.88
	Six-row hulled					
537	Oderbrucker	3.1	2.2	1.0	1.9	2.04
170	Manchuria	2.5	1.8	1.1	3.0	2.10
626	California	4.1	1.1	1.2	2.4	2.20
171	Surprise	2.5	1.3	1.1	2.5	1.85
889	Reed Triumph	2.4	1.1	1.0	1.5	1.50
182	Odessa	2.8	1.3	1.1	1.8	1.73
205	Yenidje	2.8	1.6	1.2	2.2	1.95
575	Gatami	3.7	1.8	1.1	2.9	2.38
575–1	White Gatami	3.4	1.5	1.1	1.5	1.88
	Six-row naked					
489	Nepal (White hull-less)	2.7[1]	1.3[1]	1.0	1.8	1.70
533	" (Boehme ")	4.8	1.6	1.0	1.6	2.25
262	" (Myer ")	2.4	1.1[1]	1.1	1.4	1.50
250	" (White ")	3.2	1.1	1.1	1.3	1.68
247	" (" ")	3.0	1.4	1.0	1.4	1.70
22	" (" ")	2.6	1.0	1.0	2.0	1.65
475	" (Colorado ")	3.9	1.4	1.0	1.6	1.98
595	" (White ")	2.6	1.4	1.1	1.5	1.65
598	" (" ")	2.9	1.5	1.1	1.3	1.70
	Mean of three groups					
	Two-row hulled	4.7	2.4	1.1	3.7	2.97 ± .07
	Six-row hulled	3.0	1.5	1.1	2.2	1.96 ± .05
	Six-row naked	3.1	1.3	1.0	1.5	1.77 ± .06

[1] Computed.

considerably larger number of heads per plant than did the other groups. The mean for the four-year period shows that the two-row hulled group has 2.97 ± .07 heads per plant. The six-row hulled group has 1.96 ± .05 heads and the six-row naked group 1.77 ± .06 heads per plant. The differences between these groups are shown in Fig. 16.

This figure shows a difference of 1.01 ± .09 heads per plant between the two-row hulled and the six-row hulled groups. This difference is over eleven times its probable error. Between the two-row hulled and the six-row naked groups the difference of 1.20 ± .09

heads is even greater and can be said certainly to be significant. Between the six-row hulled and the naked groups the difference of .19 ± .08 heads is not significant. The greater number of heads produced per plant by the two-row group than by the six-row hulled and the naked groups certainly accounts for a part of the differences which have been found in their yield. The fact that there is no significant difference between the number of heads produced on each plant by the six-row hulled and the six-row naked groups accounts in part, at least, for the slight difference in their yield.

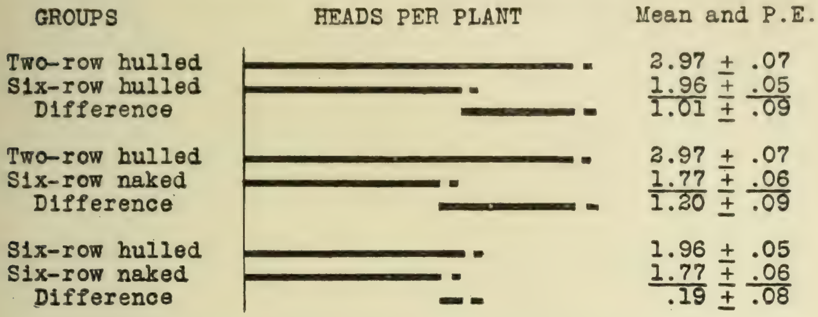

FIG. 16.—Mean number of heads per plant in 3 groups of barley, for the 5-year period, 1909–1913, with their differences in number and the probable error of the number and of the difference for each pair, shown graphically and in numerals.

LENGTH OF HEAD.

The length of head is a factor that may have a direct bearing on the yield of grain. Data on length of head have been taken in the same manner as the height of plant and a summary of the measurements for the 27 varieties and strains is given in Table 7.

All of the two-row varieties have longer heads than any of the varieties of the two six-row groups. For the five-year mean the two-row group has an average head-length of 3.1 ± .07 inches, the six-row hulled group 2.0 ± .06 inches and the six-row naked group 2.2 ± .02 inches.

Fig. 17 shows that there is a difference of .9 ± .07 inch in the length of head between the two-row hulled and the six-row naked groups. This is a difference of nearly 13 times its probable error. The two-row hulled and the six-row hulled differ in head-length by 1.1 ± .09 inches. This difference is over 12 times the probable error. The head length of the two-row group is, therefore, significantly

TABLE 7.—*Annual and Mean Length of Head and Probable Error of the Mean of 27 Varieties and Strains of Barley Grown at the Dickinson (N. Dak.) Substation for the 5-Year Period, 1909 to 1913.*

C. I. No.	Group and Variety.	Average Length of Head in Inches.					
		1909.	1910.	1911.	1912.	1913.	Mean and P. E.
	Two-row hulled						
531	Hannchen	2.7	2.4	2.8	2.7	2.8	2.7
681	Hanna No. 1	3.0[1]	3.0	2.6	3.5	2.9	3.0
625	Princess	2.8[1]	2.8	2.5	2.8	3.0	2.8
658	White Smyrna (Ouchac)	2.8[1]	3.2	2.8	3.0	2.3	2.8
530	Chevalier II	3.2	3.5	3.7	3.5	3.1	3.4
637	World Champion	3.4	3.5	3.1	4.0	4.0	3.6
189	Kitzing	3.1	2.7	2.5	2.5	3.1	2.8
158	Bavarian	3.5	3.4	2.9	3.0	3.0	3.2
207	Lower Frankish	3.2	3.3	3.0	3.0	3.0	3.1
	Six-row hulled						
537	Oderbrucker	2.5	2.7	2.4	2.5	2.2	2.5
170	Manchuria	1.8	2.7	2.3	2.3	2.3	2.3
626	California	1.9	1.9	1.9	1.8	1.4	1.8
171	Surprise	2.0	2.4	2.1	1.5	2.0	2.0
889	Reed Triumph	2.3	1.8	2.6	2.8	2.0	2.3
182	Odessa	1.9	2.3	2.1	2.0	1.9	2.0
205	Yenidje	1.9	2.1	1.7	2.0	1.5	1.8
575	Gatami	1.9	2.0	1.2	1.3	1.6	1.6
575–1	White Gatami	1.9	2.1	1.8	2.0	1.5	1.9
	Six-row naked						
489	Nepal (White hull-less)	2.3[1]	2.1[1]	2.1	2.8	2.3	2.3
533	" (Boehme ")	2.6	2.1	1.8	3.0	2.2	2.3
262	" (Myer ")	1.9	1.9[1]	2.1	2.8	2.0	2.1
250	" (White ")	2.4	2.2	1.9	2.3	1.8	2.1
247	" (" ")	2.1	2.5	2.1	2.5	2.0	2.2
22	" (" ")	2.4	2.2	2.0	2.0	2.0	2.1
475	" (Colorado ")	2.4	2.2	2.1	2.0	2.2	2.2
595	" (White ")	2.1	2.4	2.0	2.8	1.2	2.1
598	" (" ")	2.0	2.3	1.9	2.5	2.0	2.1
	Mean of three groups						
	Two-row hulled	3.1	3.1	2.9	3.1	3.0	3.1 ± .07
	Six-row hulled	2.0	2.2	2.0	2.0	1.8	2.0 ± .06
	" " naked	2.2	2.2	2.0	2.5	2.0	2.2 ± .02

[1] Computed.

greater than that of either the six-row hulled or the naked groups. The difference between the head-length of the six-row naked group and the six-row hulled group is .2 ± .06 inch, in favor of the former. This difference of 3.3 times its probable error is large enough to be of significance. These data show that the length of the head in the two-row group has been associated with a larger yield. This relation was reversed in regard to the six-row naked group and the six-row hulled group.

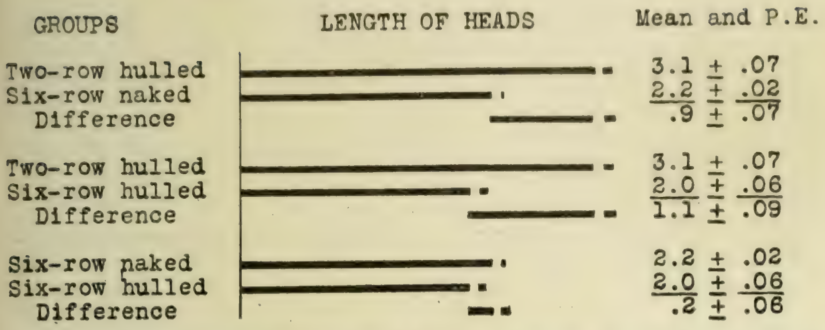

FIG. 17.—Mean length of heads in 3 groups of barley, for the 5-year period, 1909–1913, with their differences in length and the probable error of the length and of the difference for each pair, shown graphically and in numerals.

GROWING PERIOD IN DAYS.

The time required for crops to mature in the Great Plains is an important feature. Early maturity is usually a valuable asset of a variety. In Table 8 is shown the number of days during the growing period (emergence to maturity) of the 27 varieties and strains of barley for the five-year period, 1909–1913. The table shows that the earliest varieties are not the highest yielders; neither are the latest-maturing varieties among the highest in yield. The period of growth varies considerably with the season. In 1912, due to the effect of hail, the growing period was abnormally long. In each year the two-row hulled group required a longer period in which to mature than did the six-row hulled or the six-row naked groups.

For the five-year period the mean duration of the growing period for the two-row hulled group was 94 ± 1.1 days; for the six-row hulled group, 87.6 ± .7 days and for the naked group, 87.8 ± .4 days. Fig. 18 shows a difference of 6.2 ± 1.2 days in the growing period between the two-row hulled and the six-row naked groups and 6.4 ± 1.3 days between the two-row hulled and the six-row hulled groups. These differences of about five times their probable errors are significant. Between the six-row naked group and the six-row hulled group the slight difference in the growing period of .2 ± .7 day is of no significance. These data indicate that the longer period required for the two-row varieties to mature is to their advantage rather than to their disadvantage. This, of course, is not always true in seasons which are not normal, as was the case in 1910, when some of the late varieties were damaged by hail after the other varieties had been cut.

TABLE 8.—*Annual and Mean Number of Days during the Growing Period (Emergence to Maturity) and Probable Error of the Mean of 27 Varieties and Strains of Barley Grown at the Dickinson (N. Dak.) Substation for the 5-Year Period, 1909 to 1913.*

C. I. No.	Group and Variety.	Growing Period in Days.					
		1909.	1910.	1911.	1912.	1913.	Mean and P. E.
	Two-row hulled						
531	Hannchen	90	90	93	108	80	92.2
681	Hanna No. 1	85[1]	76	82	112	80	87.0
625	Princess	90[1]	90	93	108	80	92.2
658	White Smyrna (Ouchac)	84[1]	85	75	109	78	86.2
530	Chevalier II	89	90	115	112	82	97.6
637	World Champion	92	90	119	112	82	99.0
189	Kitzing	92	93	115	112	80	98.4
158	Bavarian	92	98	115	112	85	100.4
207	Lower Frankish	93	88	93	112	80	93.2
	Six-row hulled						
537	Oderbrucker	92	85	93	108	75	90.6
170	Manchuria	92	80	93	108	75	89.6
626	California	82	77	81	108	73	86.2
171	Surprise	91	88	93	108	75	91.0
889	Reed Triumph	83	85	92	108	78	87.2
182	Odessa	90	80	84	108	75	87.2
205	Yenidje	93	87	93	108	75	91.2
575	Gatami	84	77	83	103	70	83.2
575–1	White Gatami	80	77	78	106	70	82.2
	Six-row naked						
489	Nepal (White hull-less)	91[1]	85[1]	82	107	78	88.6
533	" (Boehme ")	95	85	82	107	78	89.4
262	" (Myer ")	84	85	82	107	78	89.2
250	" (White ")	84	77	82	107	78	85.6
247	" (" ")	82	77	82	107	78	85.2
22	" (" ")	84	77	82	107	78	85.6
475	" (Colorado ")	84	85	82	107	78	89.2
595	" (White ")	91	85	82	106	78	88.4
598	" (" ")	93	85	82	107	78	89.0
	Mean of three groups						
	Two-row hulled	90	89	100	111	81	94.0±1.1
	Six-row hulled	87	82	88	107	74	87.6± .7
	" " naked	87	82	82	107	78	87.8± .4

[1] Computed.

SUMMARY.

At the Dickinson substation in North Dakota two-row hulled varieties of barley have produced larger yields than the other groups. Some of the data obtained on three groups of barley, the two-row hulled nodding bearded group, six-row hulled bearded group and the six-row naked hooded group in both plat and nursery trials are presented in this paper.

An eight-year test, in field plats, of three varieties of barley repre-

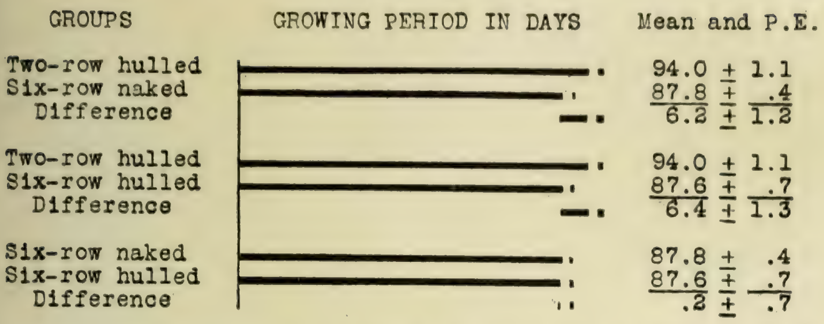

FIG. 18.—Mean duration of the growing period in days in 3 groups of barley, for the 5-year period, 1909–1913, with their differences in duration and the probable error of the duration and of the difference for each pair, shown graphically and in numerals.

senting the three groups named, shows that the two-row hulled variety outyielded the six-row hulled variety 32 percent and the six-row naked variety by 33.5 percent. There was a difference of 4 percent in yield between the six-row hulled variety and the six-row naked sort. The same three groups of barley, represented by 27 varieties, were grown in short rows in the nursery, during a period of five years, 1909 to 1913, and in the present paper a statistical study is made of the yield of both grain and straw, together with the percentage of grain in plant (excluding roots), and also height of plants, number of heads per plant, length of head and the duration of the growing period. The probable error is determined for the mean of each group for the five-year period. The groups are paired and their means and differences for the data given, together with their probable errors, are shown in graphs. The significance of the differences is determined by a comparison of the difference with its probable error. A difference three times greater than its probable error is considered significant. Greater differences are credited to the inherent characters of the varieties. A summary of the significant differences expressed in percentages is given in Table 9, the others being omitted.

The two-row hulled group exceeds the six-row hulled group in yield of grain by 43 percent; in yield of straw by 49.1 percent; has no significant difference in percentage of grain in plant or in height of plant; produces per plant 51.5 percent more heads, of 55 percent greater length, and requires a growing period 7.3 percent longer.

The two-row hulled group exceeds the six-row naked group by 44.7 percent in yield of grain and 53.3 percent in yield of straw; has no significant difference in percentage of grain in the plant; produces

TABLE 9.—*Paired Groups of Barley Showing, for Each of the Factors Considered, the Percentage of Advantage for All Significant Differences between Groups.*

Groups.	Yield of Grain.	Yield of Straw.	Percentage of Grain in Plant.	Height of Plant.	No. of Heads per Plant.	Length of Head.	Length of Growing Period.
	%	%	%	%	%	%	%
Two-row hulled	43.0	49.1	....	......	51.5	55.0	7.3
Six-row hulled	......	......	....	......	....	......	....
Two-row hulled	44.7	53.3	....	......	67.8	40.9	7.1
Six-row naked	......	......	....	6.9	....	......	....
Six-row hulled	......	......	....	......	....	......	....
Six-row naked	......	......	....	8.1	....	10.0	....

67.8 percent more heads, averaging 40.9 percent longer, and has a growing period 7.1 percent longer. On the other hand, the plants of the six-row naked group average 6.9 percent taller than those of the two-row hulled group.

The six-row naked group has plants 8.1 percent taller and heads 10 percent longer than those of the six-row hulled group.

The greater yield of both grain and straw in the two-row hulled group is accounted for, in part, by the greater number of heads per plant, the longer heads, and a longer growing period. The greater number of heads per plant is considered the most important factor. There are many other plant characters not included in this study that possibly may be determining yield factors but the data presented show some reasons why two-row hulled nodding bearded barleys produce greater yields than six-row hulled bearded or six-row naked hooded barleys at Dickinson.

SOME APPLICATIONS OF THE METHOD OF LEAST SQUARES TO AGRICULTURAL EXPERIMENTS.

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INTRODUCTION.

In attempting to improve and develop systems of farm practice, agronomists have relied chiefly upon field experiments. The great difficulties of this method of experimentation have arisen in attempting to keep constant all but one of the many variables encountered in dealing with growing crops. Until recent years very little effort has been made systematically to study these errors, to determine their magnitude, and to arrange the experiments so that they may be reduced to a minimum. Agriculturists have been slow to realize that statistical methods can be used just as effectively in agricultural experiments as in physical experiments. It is the purpose of this paper to point out some of the conditions which should be fulfilled in order to reduce the errors of agricultural experiments. Throughout the discussion it is assumed that the factor to be determined is the difference in yield of crops, grown in plats, pots, or nutrient solutions, whose treatments have been varied in some manner.

Causes of Error.

Hall and Russell[1] classify the causes of error as (*a*) lack of uniformity in soil; (*b*) lack of uniformity in conditions of growth, and (*c*) the effect of seasons. It is the task of the experimentalist to arrange the conditions so that these errors may be determined and reduced to a minimum.

Effect of Season.

Since meteorological conditions vary greatly from year to year, the season may have, in many experiments, a large influence on relative crop yields. Obviously, the only method of eliminating this source of error is to conduct the experiments in the same manner for several years. Mitscherlich[2] states that one-year field experiments can give no results of general validity, but by running a number of parallel experiments each year and continuing in identically the same way for several years, a value approximating the true value can be found, and also its probable error.[3]

A seasonal variation in yield due in part, perhaps, to the effect of seeding, but probably more to seasonal variations in the soil itself, is well illustrated by the data of Lyon.[4] From the yields for several years of a series of plats of apparently uniform land, receiving the same treatment and planted to the same crops, he found the relative productiveness varied greatly from year to year. The plats ranking high in relative yield one year usually ranked low the next and almost never the same in two consecutive years. However, for the many experiments which are conducted for only one year, the only assumption which can be made is that the seasonal error is a systematic one which cannot be eliminated.

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[1] Hall, A. D. and Russell, E. J., The Error of Experiment in Agricultural Field Trials, Chem. News 102: 180, 1910.

[2] Mitscherlich, A., Landwirtschaftliche vegatationversuche, Landw. Jahrb. 32: 773–817, 1903.

[3] According to the theory of probability, if two results are to be combined or compared they should be given weights inversely proportional to the square of their probable errors. This rule may be used in comparing the experiments of one year with another, or in comparing or combining results of similar experiments conducted at different places or by different investigators, although at the present time there are scarcely any data from which the probable error of the results can be determined.

[4] Lyon, T. L., Some Experiments to Estimate Errors in Field Plat Tests, Proc. Am. Soc. Agron., 3: 91, 1911.

Uniformity in Conditions of Growth.

Among the things affecting the conditions of growth, Hall and Russell mention the proximity of hedges and trees, and the differences between the conditions in the inside and outside rows. These difficulties are overcome to a great extent in all good field work and the errors so produced are usually negligible in comparison with other more important ones. The errors of seed and seeding may be more serious. When the same crop is grown on all plats, as in fertilizer tests, the seed may all be obtained from one source, with the probability that the viability and freedom from disease is the same for the seed on all plats. If the seeding is all done at the same time and in a uniform manner the accidental errors due to seed and seeding probably will not be large.

Professor Lyon[5] has tried the plan of planting .01 acre plats with corn, using kernels from the same ear of corn on each plat. The probable error of the mean was slightly less in this case than when the seed was selected in the usual way. In varietal tests, however, the matter is not so simple as Carleton[6] has shown. In these tests it is not only essential that the seed of the separate plats be the same, i. e., there should be no large variation in the yield of the various plats planted with the same crop during the same season, but it is also desirable that the seed be sensibly the same in viability and freedom from disease from year to year. Also the time of planting will have a large effect on the relative yield of the different varieties. Continued duplication and repetition of experiments during a series of years would be about the only course open to determine the errors due to these causes.

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[5] Lyon, T. L., A Test of Planting Plats with the Same Ears of Corn to Secure Greater Uniformity in Yield, Proc. Am. Soc. Agron., 2: 35–37, 1910.

[6] Carleton, M. A., Limitations in Field Experiments, Proc. Soc. Prom. Agr. Sci., 1909, 55–61.

UNIFORMITY OF THE SOIL.

To variations in the soil have been ascribed most of the difficulties in plat experimentation. Variations in chemical and mechanical composition, moisture content, depth, drainage, and bacterial action all affect plant growth. The early experimentalists used large plats of an acre or more, one check and one plat for each of the variables to be studied, such as tillage, fertilizer, varietal, or rotational tests. Later the plats were made smaller and several check plats were used. Now the tendency seems to be to use more duplicate plats and plats of smaller area.

EFFECT OF MULTIPLICATION OF PLATS ON PRECISION.

In order to test the effect on the precision of plat experiments of increasing the number of duplicate plats, the data of Mercer and Hall,[7] Lyon,[8] and Montgomery[9] were used. Mercer and Hall harvested one acre of mangolds in 200 sections, and one acre of wheat in 500 sections. Montgomery harvested a field plat planted to winter wheat in 224 blocks, and Lyon harvested each of 34 rows of potatoes in six sections. By treating each of these small units as a field plat and combining them in various systematic ways, groups varying from 18 to 50 units each were obtained and the probable errors of the yields of the various groups were computed.

The relative location and yields of the mangold plats are shown in Fig. 19. Twenty of these plats face the east side and ten the south, the shape or grouping being designated as 20 × 10. As nearly as can be determined from Mercer and Hall's paper, these plats extend an average of 30.25 feet from east to west and 7.2 feet from south to north. The upper figure gives the yield in pounds of the mangold roots in the respective plats. The lower figure refers to the group in which the plat is placed in the first grouping, and illustrates the scheme of grouping. These 200 plats were combined into ten equal areas so arranged as to give in each area, first, 20 distributed duplicate plats of 1/200 acre each, next 10 duplicate plats of 1/100 acre each, then 5 plats of 1/50 acre each and so on until finally one plat of 1/10 acre was obtained. In every case the allotment of plats followed the same system. Beginning at the southeast corner, the plats along each of the

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[7] Mercer, W. B. and Hall, A. D., The Experimental Error of Field Trials, Journ. Agr. Sci., 4: 107–132, 1911.

[8] Lyon, T. L., Some Experiments to Estimate Errors in Field Plat Tests, Proc. Am. Soc. Agron., 3: 97, 1911.

[9] Montgomery, E. G., Experiments in Wheat Breeding, U. S. Dept. Agr., Bur. Plant Industry, Bul. 269: 37, 1913.

EAST

376 1	371 7	355 3	356 9	335 5	332 1	335 7	340 3	352 9	352 5
316 2	338 8	336 4	356 10	332 6	340 2	339 8	359 4	365 10	349 6
326 3	326 9	335 5	343 1	330 7	328 3	350 9	339 5	337 1	362 7
317 4	343 10	330 6	327 2	336 8	340 4	335 10	301 6	348 2	357 8
321 5	332 1	317 7	318 3	306 9	331 5	335 1	311 7	329 3	353 9
335 6	349 2	332 8	358 4	325 10	348 6	328 2	290 8	326 4	323 10
341 7	346 3	321 9	321 5	314 1	340 7	337 3	321 9	329 5	317 1
347 8	363 4	349 10	341 6	329 2	321 8	337 4	300 10	364 6	310 2
354 9	365 5	350 1	339 7	316 3	342 9	335 5	331 1	345 7	327 3
309 10	352 6	328 2	297 8	308 4	343 10	349 6	372 2	362 8	346 7
349 4	335 10	323 6	325 2	322 8	348 4	350 10	354 6	350 2	360 8
343 5	346 1	300 7	312 3	313 9	331 5	347 1	324 7	336 3	339 9
338 6	327 2	323 8	296 4	311 10	335 6	320 2	318 8	343 4	333 10
339 7	384 3	322 9	331 5	277 1	299 7	332 3	302 9	318 5	306 1
314 8	325 4	330 10	328 6	301 2	316 8	338 4	310 10	304 6	302 2
300 9	329 5	322 1	310 7	309 3	342 9	350 5	335 1	320 7	278 3
369 10	341 6	344 2	324 8	316 4	342 10	351 6	324 2	310 8	309 4
298 1	302 7	325 3	300 9	286 5	330 1	324 7	322 3	309 9	322 5
324 2	316 8	310 4	317 10	295 6	308 2	295 8	267 4	307 10	290 6
330 3	306 9	306 5	306 1	291 7	321 3	325 9	288 5	302 1	310 7

WEST

FIG. 19.—Plan and yield of mangold plats.

successive files were numbered from south to north, finishing at the northwest corner. The plats were numbered in cyclic order from 1 to 10, omitting the three succeeding numbers at the end of each cycle. All plats numbered 1 were grouped together and considered as duplicates of one test, and those numbered 2, 3, 4, etc., were grouped as duplicates of tests 2, 3, 4, etc., respectively. From the crop yields obtained from the plats combined in this manner, the probable error (r) of the yield of each plat in each group was computed, together with the probable error of the mean (r_0) yield of the plats in each group, from the relation

$$r = 0.6745\sqrt{\frac{\Sigma V^2}{n-1}} \qquad \text{and} \qquad r_0 = 0.6745\sqrt{\frac{\Sigma V^2}{n(n-1)}} = \frac{r}{\sqrt{n}}.$$

where ΣV^2 is the sum of the squares of the residuals in each group and n is the number of plats in each group.

Using the data from Fig. 19, we have ten groups of plats, each group consisting of 20 duplicated plats of 1/200 acre each well distributed over the acre. A summary of the least square computations is given in Table 1.

TABLE 1.—*Mercer and Hall's Mangold Plats Grouped 20×10.*

Group No.	Total Yield, Lbs.	Deviation from Mean, Lbs.	Average Yield per Plat, Lbs.	Σv^2	r Lbs.	r %	r_0 Lbs.	r_0 %
1	6,536	+35.5	326.8	9,391	15.0	4.59	3.4	1.04
2	6,572	− .5	328.6	6,035	12.0	3.66	2.7	.82
3	6,571	+ .5	328.6	7,952	13.8	4.20	3.1	.94
4	6,591	−19.5	329.6	10,927	16.2	4.91	3.6	1.10
5	6,567	+ 4.5	328.4	7,033	13.0	3.95	2.9	.88
6	6,660	−88.5	333.0	8,278	14.1	4.23	3.2	.95
7	6,510	+61.5	325.5	8,596	14.3	4.41	3.2	.99
8	6,517	+54.5	325.8	8,117	13.9	4.28	3.1	.96
9	6,539	+32.5	327.0	7,587	13.5	4.12	3.0	.92
10	6,652	−80.5	332.6	7,486	13.4	4.03	3.0	.90
Mean....	6,571.5	37.8 0.58%	328.6	8,077	13.9	4.25	3.1	.95

The various groups show a very uniform yield, the mean deviation from the mean or average deviation (A. D.) being 38 lbs. or 0.6 percent, and the maximum variation of the yield of two groups (6 and 7) being only 2.3 percent of the mean. These groups are built up of plats whose maximum variation in yield (376–267) is 33 percent of the mean. The probable error of the mean of the twenty plats in each group varies from 0.8 percent to 1.1 percent with an average of 0.95 percent for all the groups. Accordingly, if any two of these groups had received some difference in treatment, and if their mean yields differed by more than 3.3 lbs. it is more than an even chance that part of the actual difference in yield was due to this difference in treatment. The actual maximum variation is more than twice this amount (7.5 lbs.) with a probability of 0.23. It is a 10 to 1 chance that any difference in mean yield of more than 10.6 lbs. is not due to accidental errors in the experiment, and it is a 100 to 1 chance that a difference in mean yield of 16.3 lbs. would be due in part to the difference in treatment. Now this precision was obtained by building up in one group 20 distributed duplicate plats each of which has a probable error of about 14 lbs. In other words, by combining 20 plats, each having a probable error of about 4.25 percent, we obtain a group whose mean has a probable error of about 1 percent.

By properly combining these plats in pairs new plats were obtained which had the same length east to west of the original plats but twice the width south to north. The field then had 100 plats of 1/100-acre each arranged 10 × 10, or ten plats facing each side. These plats were numbered and grouped according to the foregoing scheme and the probable errors again determined. By combining the adjacent plats in another way a field with 20 plats south to north and 5 plats east to west (20 × 5) was obtained, each plat of 1/100 acre. Continuing in this way fields arranged in plats 50 plats 10 × 5, and 5 × 10; 40 plats 4 × 10; 20 plats, 20 × 2, and 4 × 5, and finally ten single plats (2 × 5) of 1/10 acre each were obtained. Table 2 shows the summary of the least square computations.

Table 2.—*Summary of Least Square Computations of Mangold Plats.*

Grouping.	No. Plats per Group.	Mean Yield per Plat (Lbs.).			A. D.	Mean r.	Mean r_0.
		Max.	Min.	Average.			
					%	%	%
20×10	20	333.0	325.5	328.6	0.58	4.25	0.95
10×10	10	673.5	646.8	657.2	.96	3.55	1.12
20× 5	10	679.8	645.3	657.2	1.09	3.58	1.13
10× 5	5	1,372	1,271	1,314	2.03	2.71	1.21
5×10	5	1,337	1,270	1,314	1.26	3.06	1.37
4×10	4	1,716	1,592	1,643	1.41	2.55	1.28
20× 2	4	1,683	1,600	1,643	1.22	2.95	1.49
4× 5	2	3,395	3,184	3,286	1.98	2.07	1.46
2× 5	1	6,853	6,293	6,572	2.48	....	....

Although we are treating these ten groups as unrelated yields, yet in reality all have had the same treatment and their means should be the same within the error of the experiment. Of the ten means in each grouping the table gives the highest, the lowest and the average value. The average deviation (A. D.), was obtained by taking the average (without regard to sign), of the ten deviations from the average yield (6,572 lbs.) in each tenth acre group, and is expressed in percentage of 6,572 lbs. All the figures in this column are comparable.

Since the probable error (r) of each plat is expressed in percentage of the mean yield per plat, the figures in column 7 are comparable. These figures indicate that one plat of 1/20-acre ($r = 2.07$ percent) is about twice as accurate as one plat of 1/200-acre ($r = 4.25$ percent); or that four distributed plats of 1/200-acre each would probably be as reliable as one plat of 1/20-acre. Too much reliance, however, must not be placed on probable errors computed from the yields of only a few plats. In the last column is given the probable error of the mean yield per plat in each group and this is the factor in which we are most interested. These r_0*'s* are expressed in percentage (of column 5) and are, therefore, directly comparable. The groupings of 10, 5, and 4 plats, respectively, should have approximately the same probable error for each member of the pair. Taking their averages we get for the r_0's: 20 plats, $r_0 = 0.95$ percent; 10 plats, $r_0 = 1.12$ percent; 5 plats, $r_0 = 1.29$ percent; 4 plats $r_0 = 1.38$ percent; 2 plats $r_0 = 1.46$ percent. This shows the increase in precision of the greater number of smaller plats of the same total area.

The acre of wheat harvested by Mercer and Hall in 500 plats was arranged and combined in the same manner as the mangold plats and the probable error of the ten groups computed. For the first grouping all the plats were used, but for the others, the last row of plats on the east side was omitted, leaving 480 plats arranged 20 × 24. The dimensions of these plats were about 10.82 feet by 8.05 feet.

TABLE 3.—*Mercer and Hall's Wheat Plats. Ten Groups. Summary of Least Square Computations.*

Grouping.	No. Plats per Group.	Mean Yield per Plat.			A. D.	Mean r.	Mean r_0.
		Max.	Min.	Average.			
		lbs.	*lbs.*	*lbs.*	%	%	%
20 × 25	50	4.04	3.87	3.95	0.96	8.17	1.15
20 × 24	48	4.04	3.86	3.95	.98	7.87	1.14
20 × 12	24	7.96	7.83	7.90	.50	6.48	1.33
10 × 24	24	8.13	7.74	7.90	1.70	7.12	1.45
10 × 12	12	16.04	15.12	15.77	1.44	5.87	1.69
10 × 6	6	32.29	31.21	31.59	.86	4.51	1.84
5 × 12	6	33.22	30.01	31.59	2.49	4.97	2.03
5 × 8	4	48.51	45.23	47.39	1.61	4.53	2.26
5 × 4	2	98.16	91.28	94.77	2.19	4.24	3.00
5 × 2	1	205.56	173.57	189.54	4.42	....	....

This again shows that the greater the number of replicate plats of the same total area the higher the precision. A summary of the computations is shown in Table 3.

Because of the great consistency of these figures, the same field was grouped into twelve groups. In this case a very uniform distribution of plats was obtained by numbering from 1 to 12 in cyclic order. A summary of the least square computations is given in Table 4.

TABLE 4.—*Mercer and Hall's Wheat Plats. Twelve Groups. Summary of Least Square Computations.*

Grouping.	No. Plats Per Group.	Mean Yield per Plat.			A. D.	Mean r.	Mean r_0.
		Max.	Min.	Average.			
		lbs.	*lbs.*	*lbs.*	%	%	%
20×25	41–42	4.06	3.84	3.95	....	8.01	1.24
20×24	40	4.05	3.84	3.95	1.29	7.88	1.25
20×12	20	8.11	7.57	7.90	1.75	6.48	1.44
10×24	20	8.13	7.68	7.90	1.90	6.79	1.52
10×12	10	16.29	14.88	15.71	2.95	5.43	1.78
10× 6	5	32.43	30.75	31.59	1.96	4.45	1.99
5×12	5	32.35	29.91	31.59	3.03	5.06	2.26
4×12	4	41.73	37.92	39.49	3.26	4.81	2.40
4× 3	1	168.58	144.77	157.95	4.09	....	....

The results in this case are in all respects similar to the previous ones obtained from the wheat and mangold plats.

Montgomery harvested a field plat of Turkey winter wheat in 224 blocks. The field was 88 feet by 77 feet, and each block was 5.5 feet square. In order to use all the plats they were combined into seven groups. In each grouping the plats were numbered from 1 to 7 in cyclic order, omitting one number after each cycle. This system did not give a very uniform distribution in all cases. The various groupings and a summary of the least square computations are shown in Table 5.

TABLE 5.—*Montgomery's Wheat Plats. Summary of Least Square Computations.*

Grouping.	No. Plats per Group.	Mean Yield per Plat (Grams).			A. D.	Mean r.	Mean r_0.
		Max.	Min.	Average.			
					%	%	%
16×14	32	702	653	681	2.29	8.61	1.52
16× 7	16	1,400	1,319	1,362	1.41	7.53	1.88
8×14	16	1,405	1,323	1,362	1.98	7.40	1.85
8× 7	8	2,768	2,627	2,723	1.38	6.52	2.31
4×14	8	2,779	2,665	2,723	1.15	6.29	2.25
4× 7	4	5,623	5,228	5,447	1.68	6.05	3.02
2×14	4	5,722	5,179	5,447	3.17	4.78	2.39
2× 7	2	11,607	10,418	10,894	3.03	4.59	3.24
1×14	2	11,260	10,428	10,894	1.98	4.36	3.08
1× 7	1	23,537	20,386	21,788	4.56	....	....

Montgomery has combined the 224 blocks into 56 groups of 4 blocks each, 28 groups of 8 blocks each, and 14 groups of 16 blocks each, made up first of adjacent blocks, and then of systematically distributed ones. In each arrangement the coefficient of variability is much less for the groups of systematically distributed plats. In the present case, the total area is always divided into seven equal groups, each having an area of about .022 acre, and the probable error determined from the variations in yield of its plats. The column r_0 shows that the probable error can be reduced from 3.2 percent in the case of one repetition to about two-thirds this amount for seven repetitions and to about one half for thirty-one repetitions, always keeping the total area the same.

The only other data found suitable for this type of computation was that of the yield of 34 rows of potatoes given by Lyon. By omitting the two outside rows on each side of the field, 30 rows, each harvested in six sections, remained. This gives 180 plats of .0047 acre or approximately 1/200 acre each. By combining these as were the mangold plats, 10 groups of .085 acre each were obtained, each group consisting of from 1 to 18 plats. These plats were combined and grouped as shown in Table 6.

TABLE 6.—*Lyon's Potato Plats. Summary of Least Square Computations.*

Grouping.	No. Plats per Group.	Mean Yield per Plat (Lbs.).			A. D.	Mean r.	Mean r_0.
		Max.	Min.	Average.			
					%	%	%
30×6	18	23.7	22.1	22.7	1.34	14.6	3.43
30×3	9	47.5	43.3	45.4	2.16	11.9	3.95
15×6	9	47.5	43.4	45.4	2.42	12.9	4.31
30×2	6	71.0	64.4	68.1	3.13	10.4	4.25
10×6	6	73.2	64.8	68.1	4.09	12.1	4.93
10×3	3	146.0	122.4	136.3	3.85	10.5	6.09
5×6	3	148.6	126.4	136.3	4.08	11.6	6.69
5×2	1	494.4	335.4	408.9	10.4	....	....

Although the absolute precision in this case is not as great as in the case of the wheat and mangolds, yet the relative results are much the same. The probable error of the mean plat-yield of the groups consisting of 9 duplicate plats is 4.1 percent as compared with 6.4 percent for groups of 3 plats. By combining 18 plats we obtain a mean yield of about 22.7 lbs. with a probable error of 3.4 percent (0.8 lbs.), although the actual yields of the individual plats may vary from 10 lbs. to 35 lbs. each. The values of r show that the larger plats are on the whole slightly more accurate than the smaller ones, but the values are not so consistent as are those of r for the wheat and mangold plats.

In the case of the field of mangolds, wheat, or potatoes, the area of each group of plats is one tenth, one twelfth, or one seventh of the area of the field, regardless of the system of grouping. Hence the mean total yield of each group will always be the same for any arrangement of plats. Since all groups in each field had the same treatment, their actual total yields should be the same within the experimental error, and their deviations from the mean furnish further evidence of the desirability of replication. The columns A. D. show the average deviation from the mean of the total yield of each group, and give an idea of the general consistency of the data. On the whole the average deviation increases with the decrease in the number of plats, being much larger when the total area of a group consists of one contiguous plat. Probably the chief cause for this is the lack of uniformity of the soil. When many small, well distributed duplicate plats are used, soil of all degrees of productivity is likely to be found in each group of duplicate plats, and this is the main argument for replication in field and pot experiments. Aqueous nutrient solutions can be duplicated much more accurately than either plats of ground or pots of soil can be.

To illustrate one application of probable error to field experiments, we will assume that Montgomery's field plat had been divided into 28 plats according to the 4 × 7 grouping (see Table 5) and planted to seven varieties, each repeated three times in accordance with the systematic distribution used in this paper. What is the probability that a difference in yield of 10 percent between any two varieties is due entirely to experimental error? The probable error of the mean plat yield is about 3 percent, according to Table 5. Hence the probable error of their difference in yield is $\sqrt{3^2 + 3^2}$, or 4.25 percent. A 10 percent difference is 2.3 times the probable error, and the chance of an error of $2.3r$ is about 1 to 7. Therefore, if the yield of the two varieties, each having a probable error of 3 percent differed by 10 percent, the chances are 7 to 1 that the difference is entirely due to experimental error. By decreasing the size of each plat one half and doubling the number (8 × 7 grouping) the probable error of the mean plat yield would be reduced to 2.3 percent, and the probable error of the difference in yield of the two varieties would be 3.25 percent of their mean. The chances of an error as large as 10 percent of their mean would be about 1 to 25. This increase in precision would ordinarily be greater if the area, as well as the number, of plats had been doubled. Under these conditions 8 replications would appear to be sufficient where the experimentalist is not concerned with differences of less than 10 percent.[10] However, in calculations of this sort too much reliance must not be placed upon probable errors determined from only a few varieties. For example, the probable errors (r_0) actually ranged from 2.1 percent to 4.6 percent for the 4×7 grouping and from 1.6 percent to 3.6 percent for the 8×7 grouping. In comparing two single plats 5.5 feet square, it is a 1 to 4 chance that differences of 25 percent in yield are due entirely to experimental error. It should be noted in the above illustration that check plats and "normal yields" were neither used nor needed.

Effect of Size of Field Plats on Precision.

The foregoing data do not shed much light on the optimum size of field plat. They show that down to .0007 acre when wheat is grown, a number of small plats is much better than the same total area all in one plat, and also indicate that one large plat is better than one small one. But it must be borne in mind that these plats did not receive different individual treatment of any kind before harvest. Whether the actual gain under ordinary conditions is as large as indicated by these plats, experiment alone can prove. So far no data has been found that can furnish any information on this point. Lyon,[11] says "There seems to be little gain in accuracy by using plats larger than one fiftieth of an acre in size, when the yield of crop is made the criterion. For accuracy in sampling soil the smaller the plat the better. When it is possible to give small plats careful treatment, and to repeat each treatment several times the small plats are to be preferred to the large ones." Mercer and Hall recommend five replicated plats of 1/40 acre each, well distributed over the area, in preference to one plat of 1/8 acre. This they say reduces the experimental error to about 2 percent of the result if the land is at all suited to experiment.

The smallest plat used by the Bureau of Soils is ten feet square, or about 1/435 acre. A common size of plat is one rod square, or 1/160 acre. Plats of this size with good care give satisfactory results even when planted to such crops as corn, of which there are only 32 plants on the smaller plat. The results of the above computations indicate

[10] Montgomery considers fifteen to twenty replications necessary using the single blocks, if comparable results are to be obtained the first year. Piper and Stevenson (Proc. Am. Soc. Agron. 2: 70–76, 1910), recommend, for varietal and similar tests of small grains, two to five replications in plot tests of 1/40 to 1/10 acre or ten replications in row tests, as minimum standards.

[11] Lyon, T. L., Some Experiments to Estimate Errors in Field Plat Tests, Proc. Am. Soc. Agron. 3: 114, 1911.

that by using small replicate plats the experiments can be conducted in a more satisfactory manner and on a smaller area of ground than is usually devoted to single plat treatments, and with probably only a slight increase in labor and care in seeding and culture. When there are no duplications, the errors due to variations from seed and seeding, mechanical or insectial injury are likely to become large. In replicated plats the effect of such errors may be reduced somewhat by assigning weights to the plats. One set of weights may be assigned by multiplying the yield of each plat by a factor which is estimated to be inversely proportional to the loss of yield due to damage by insects, and other sets of weights for mechanical injury, etc.

Another factor which will affect the optimum size of plat is the number of duplications. The number of duplications will probably not be determined by the space available but by the amount of labor involved, since for any given space the greater the number of plats of the same total area the greater the precision will undoubtedly be. The experimentalist will need to decide what precision is necessary for his experiment before he decides on the number of replications. Extreme accuracy, when it involves much time, is as much to be avoided as inaccuracy.

There is one great satisfaction in replication to both the field experimenter and the readers of literature in this field. It enables both to determine whether the results show any valid conclusions by giving them a means to estimate the precision of the work. For example if plat *A* treated with fertilizer *a* shows a yield 50 percent greater than plat *B* treated with fertilizer *b*, it does not at all follow that fertilizer *a* is better than fertilizer *b;* but if several distributed duplicates of plat *A* with a probable error of the mean yield of 5 percent gave a yield of 50 percent more than several duplicates of plat *B* distributed in the same area and also having a probable error of 5 percent, then it would be more than a 400,000 to 1 chance that fertilizer *a* is better than fertilizer *b*. Among all the experiments with field crops there are few in which any measure of precision can be found, and careless work cannot be distinguished from the best. Usually the only criterion to be found is the deviations of yield in the check plats. When in any experiment several check plats have been used, well distributed over the area, planted to the same crop, and having had the same culture and treatment, the probable error (r) of a check plat can be determined, and the assumption made that each of the treated plats is equally likely to have the same error.

Use of Check Plats.

The common practice seems to be to use one third to one fifth of the plats as checks. In most of these experiments the factor desired is the difference between the yield of the treated and the untreated plats. In order to secure this the so-called "normal" yield of the treated plats is found. Occasionally this is taken to be the mean of all the check plats in the area, but more often it is determined by taking the weighted mean of the two nearest checks, the weights being inversely proportional to the distances of the checks from the treated plat. If the soil were uniform and all variations in the yield of the checks were due to accidental errors the former method would be the correct one; if practically all variations in yield were due to variations in the soil, the latter method would be the correct one, provided the fertility varied uniformly in one direction (increasing or decreasing) from one check plat to the next. As this is seldom likely to be the case, the second method is only an approximation.

However, there is no reason why both methods cannot simultaneously be used, giving them any relative weights the investigator may desire. For example consider two treated plats A and B lying between two checks C_1 and C_2 in the order C_1, A, B, C_2, and having yields c_1, a, b, c_2, the mean yield of all the check plats in the area being c. Then according to the first system, the normal yield of plat A would be c; according to the second system the normal yield would be $2/3c_1 + 1/3c_2$. Combining both systems with equal weight the normal yield of A would be $1/2(c + 2/3c_1 + 1/3c_2)$. For any other weights, p_1 and p_2 the normal yield would be $\frac{p_1 + p_2\,(2/3c_1 + 1/3c_2)}{p_1 + p_2}$. The method used by the Office of Cereal Investigations, Bureau of Plant Industry gives $1/2(c + c_1)$ as the normal yield of plat A, and $1/2(c + c_2)$ for plat B.[12] Some combination of the two methods represented by the general formula above would give due weight, both to the uniform variations in the soil, and to those other factors whose effects may be classified as accidental errors. With a large number of small, well-distributed duplicate plats the question of normal yield is not so important; for the probability is that all grades of soil will be represented in nearly the same proportion in each group of plats. This gives the same effect one would obtain with an area of uniform soil. If, in this case, the average yield of all the checks in the area is taken as the normal yield, theoretically there should be so many more checks than plats of a single treatment that the probable error of the mean check plat yield is small in comparison with the probable error of the mean yield of each group of treated plats. The reason for this is that the mean check plat yield enters into the computations of all groups of treated plats. The exact number is a matter of judgment, and depends upon the precision desired and the labor to be spent upon the experiment.

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[12] Carleton, M. A., Limitations in Field Experiments, Proc. Soc. Prom. Agr. Sci., 1909: 56.

SUMMARY.

The estimation of the probable errors of a large number of small duplicate plats well distributed in the area devoted to a field experiment indicates that the precision of agricultural experiments can be increased by replicating the experiments on small plats. Replication is urged not only for giving greater precision in experiments in which the results justify the increased labor, but also for furnishing a means whereby the experimenter and his reading public may determine what reliance can be placed upon the data and conclusions of the experiment. Replication also lessens the uncertainties involved in the use of check plats, and may decrease the total area required for the conduct of field experiments.

MUTUAL INFLUENCE OF CERTAIN CROPS IN RELATION TO NITROGEN.

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During the course of some preliminary experiments upon the relation of crop development to subsequent nitrification in soil samples from California and the District of Columbia, certain data have been secured that should be considered both in experiments in soil improvement by green manuring and also in the comparative studies of crop development as well as in investigations in soil biology.

In the following experiments the various crops tested were grown in duplicate and two types of soil were used. One type was a rather stiff silty clay loam from the flats of the Potomac River in the District of Columbia. The other soil was a light, rather coarse loam from near Riverside, California. The total supply of each soil was first very thoroughly mixed in order to make it uniform throughout, and then equal quantities were placed into tarred, paraffined wire baskets. Where legumes were to be grown the soil was inoculated with a pure culture of the nitrogen-fixing bacteria which form root nodules.

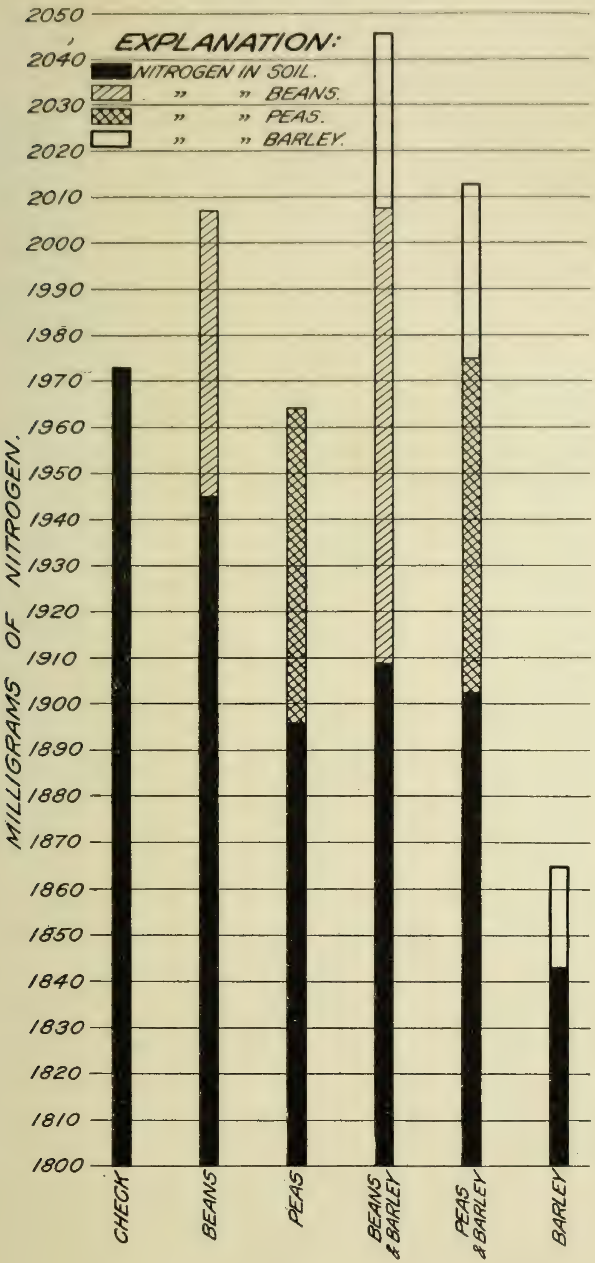

FIG. 20.—550 grams of District of Columbia soil were used in each pot. Milligrams of nitrogen present per kilogram in soil and in dry crop after eighty days when legumes and non-legumes are grown separately and together.

Optimum moisture conditions were maintained by adding sufficient distilled water every two days to replace the loss by evaporation and transpiration.

After eighty days' growth all plants and roots were carefully removed and dried. Total nitrogen determinations were made by the Kjeldahl process on soil and crop from each basket. Where combinations of legumes and non-legumes were grown, separate determinations were made on each. As shown by Fig. 20, both the legume and the non-legume show an appreciable gain in percentage of nitrogen when grown together. In other words, beans and barley and peas and barley show a truly symbiotic relationship in regard to their nitrogen percentage.

There is a reduction in the percentage of nitrogen in the soil by all of the plants tested, provided the entire plant including its roots is removed from the soil before analysis.

Lyon and Bizzell[1] and Lipman[2] have called attention to the fact that if a non-legume and a legume are grown together there occurs an actual gain in the percentage of nitrogen of the non-legume. Neither these authors nor other investigators studying similar phenomena have recognized that the leguminous crop also gains in nitrogen.

A totally different point which seems to deserve emphasis is the difference in the effect of the growth of a given plant upon the nitrogen content of different soils. An examination of Figs. 21 and 22 will show that an actual loss of soil nitrogen has taken place with many of the pots growing non-leguminous crops. While this is within the range of experimental error for rye and kafir grown in California soil, the loss when these crops are grown in District of Columbia greenhouse soil has been considerable. Barley, on the other hand, has caused a very decided nitrogen loss in both soils. These losses are actual. That is, they are over and above the nitrogen utilized by the plants, while in the case of the legumes the crop which has been removed contains as much or more nitrogen as the soil has apparently lost.

The effect upon the nitrifying power of soils resulting from growing plants and then removing them, roots and all, is naturally less than where only the tops are removed and the roots are left to decay in

[1] Lyon, T. L. and Bizzell, J. A., A Heretofore Unnoted Benefit from the Growth of Legumes, Cornell Univ. Agri. Expt. Sta. Bul. No. 294, 1911. See also this JOURNAL, pp. 65–82, Vol. 5, 1913.

[2] Lipman, J. G., A Method for the Study of Soil Fertility Problems, Journal of Agri. Sci., 3: 297–300, 1910.

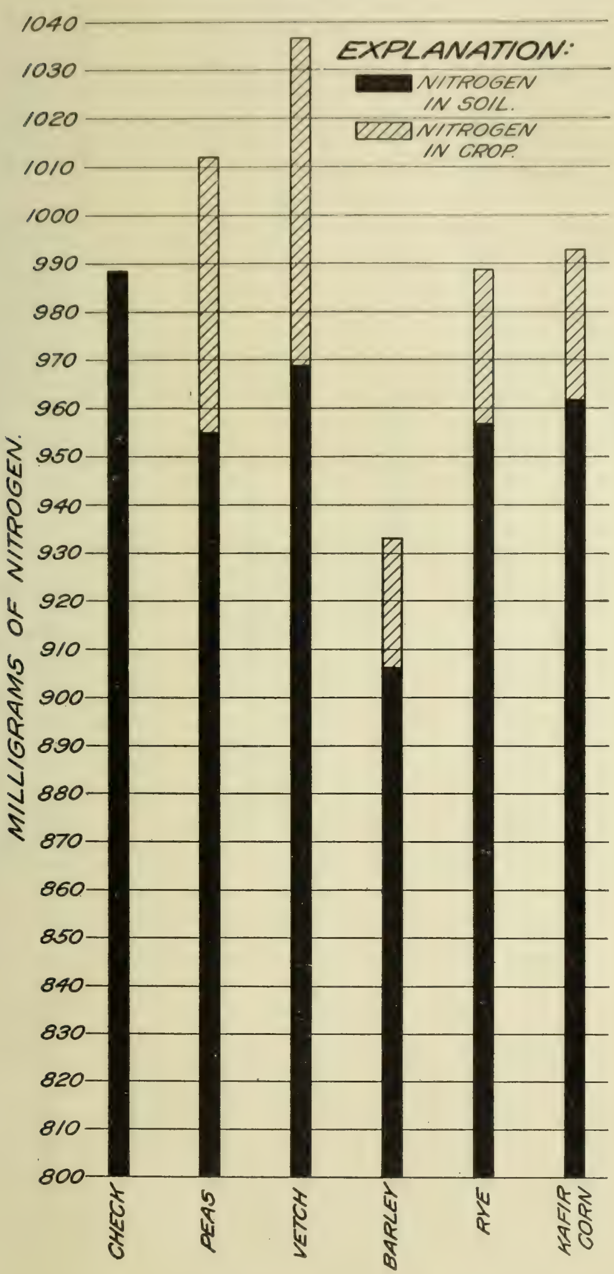

FIG. 21.—600 grams of California soil were used in each pot. Milligrams of nitrogen present per kilogram in soil and in dry crop after eighty days.

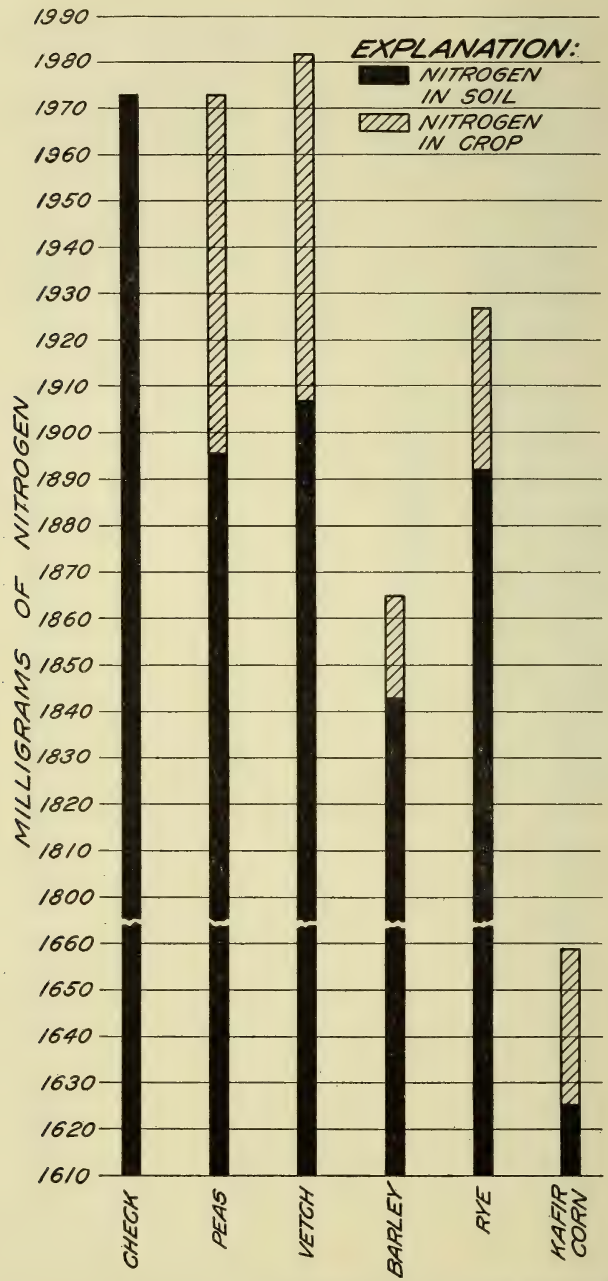

FIG. 22.—550 grams of District of Columbia soil were used in each pot. Milligrams of nitrogen present per kilogram in soil and in dry crop after eighty days.

the soil. That some effect may be noticed in some soils, however, is shown in Fig. 23.

Lyon and Bizzell[3] in explaining discrepancies between results secured from tests of the nitrifying power of South Carolina soils reported by Stevens and Withers and by Kellerman and Robinson have pointed out that a more rapid nitrification takes place in soil supporting a growth of alfalfa than similar soil supporting a crop of timothy. Kellerman and Allen,[4] however, found that in irrigated desert soil the age and condition of an alfalfa crop bore little if any reference to the potential rate of nitrification. These discordant results substantiate the tentative conclusions we deduce from the

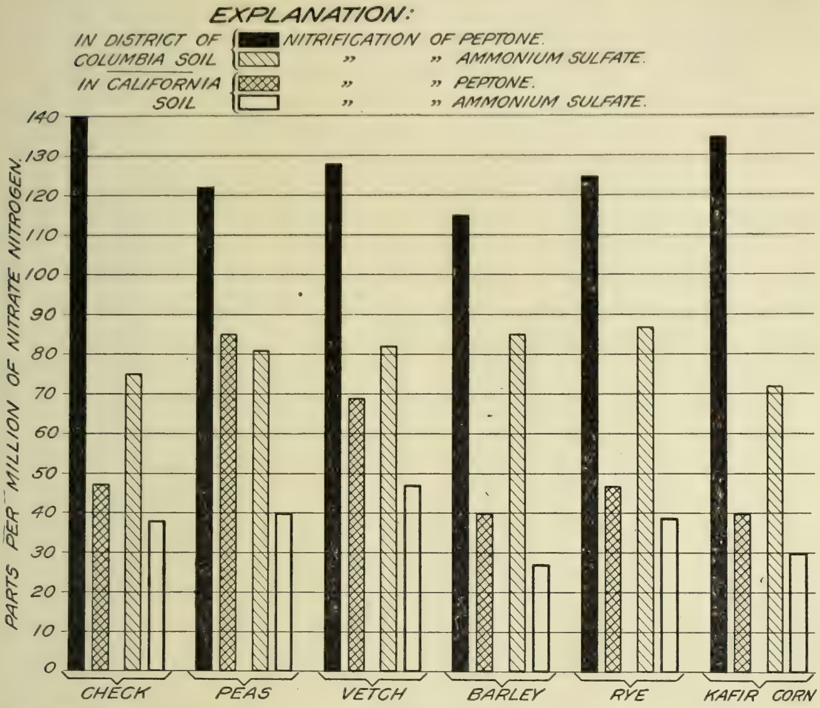

FIG. 23.—Relative nitrifying power of District of Columbia soil and of California soil affected slightly by growth of crops.

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[3] Lyon, T. L., and Bizzell, J. A., The Relation of Certain Non-leguminous Plants to the Nitrate Content of Soils, Journ. Franklin Inst., 171: 1–16, 205–220, 1911. See also Memoir No. 1, Cornell Univ. Agri. Expt. Sta., 1913.

[4] Kellerman, Karl F., and Allen, E. R., Bacteriological Studies of the Soils of the Truckee-Carson Irrigation Project, U. S. Dept. Agr., Bur. Plant Ind. Bul. 211, 1911.

above preliminary experiments: that the effect of a given crop upon two different soils may be very different both in regard to its effect upon the total soil nitrogen and upon the nitrifying power of the two soils.

PERCENTAGE OF PROTEIN IN NON-LEGUMES AND LEGUMES WHEN GROWN ALONE AND IN ASSOCIATION IN FIELD MIXTURES.[1]

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The recent publications[2] concerning the effect of legumes upon the nitrogen content of the associated non-legume grown in mixtures in pots and in experimental plots raised the question in the minds of the authors of the present paper as to how far the logical conclusions from these experiments are applicable to the ordinary farm mixtures of legumes and non-legumes on fields of average fertility in different sections of the country and upon the different types of soils as well as in different seasons.

As an instance of the conclusions drawn from one of the publications above referred to, the following article[3] seems worthy of note:

> The Planting of Non-legumes with Legumes. In the spring, when clover is generally seeded and when plans for cover-crops, green manures, and mixed forage crops are being made, the value of having leguminous plants associated with non-leguminous plants should be kept in mind. The general value of

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[1] Presented at the annual meeting of the Society, Nov. 17, 1913.

[2] T. L. Lyon and J. A. Bizzell, Availability of Soil Nitrogen in Relation to the Basicity of the Soil and to the Growth of Legumes, The Journal of Industrial and Engineering Chemistry, 2: 313–315, July, 1910. J. G. Lipman, A Method for the Study of Soil Fertility Problems. Journal of Agricultural Science, 3: 297–300, Sept., 1910. Annual Report, U. S. Office of Experiment Stations, for 1909, Oct. 10, 1910, p. 150. T. L. Lyon, The Influence of Alfalfa on Nitrification in the Soil and on the Nitrogen Content of Accompanying Vegetation, Proc. Am. Soc. Agronomy (1907–1909), Nov. 15, 1910, 1: 217–221. T. L. Lyon and J. A. Bizzell, A Heretofore Unnoted Benefit from the Growth of Legumes, Cornell Expt. Sta. Bul. No. 294, March, 1911. J. G. Lipman, The Associative Growth of Legumes and Non-legumes, N. J. Agr. Expt. Sta. Bul. No. 253, Oct. 1, 1912. See also Journal of the Am. Soc. of Agronomy, Vol. V, No. 2, 1913.

[3] The Announcer of the College of Agriculture, Cornell University, Ithaca, N. Y., Vol. II, No. 6, p. 22 (March, 1913). See also Weekly News Letter to Crop Correspondents, U. S. Department of Agriculture, Vol. I, No. 24, Jan. 21, 1914.

legumes in soil improvement has been admitted, but recent investigations reported in Bulletin No. 204 of this experiment station, entitled "A Heretofore Unnoted Benefit from the Growth of Legumes," are of especial interest to farmers. Not only does the legume gather nitrogen from the atmosphere by means of bacteria living in the nodules on its roots, thereby itself making a larger growth, *but some of the nitrogen so gathered is passed on to the grass, grain, or other non-legume associated with it. The result is a larger growth of the non-legume, and also a higher content of protein,* or nitrogenous material, which considerably increases its value as food for stock. Such benefit has been noted from the growth of clover and timothy, alfalfa and timothy, and oats and peas. Other combinations have not been studied. The increased growth of plants in combination over that of single crops, together with the improved composition of the former, has resulted in some cases in an increase of more than *thirty percent* in the production of *protein per acre.* This increased value probably extends to the roots and stems left in the soil, and means much in the production of food for stock and in soil improvement. (Italics ours.)

It is not the intention of the authors to consider any phase of the question other than the effect of the association upon the percentage composition of the constituents of the mixtures. It has been felt that the great agronomic importance of any practice which apparently promises to materially increase the protein content of the non-leguminous forage plants, etc., grown on the farm is such that any exceptions to the general application of the method on a field scale should be pretty definitely worked out before the matter is passed on unreservedly to the practical farmer. If it shall prove that there are sections of the country or certain soil types where such an effect cannot reasonably be expected, it is important not to draw too general a conclusion as to the application of the method from the data at present at hand. It is hoped that the results of the analyses of the constituents of the mixtures here reported will serve to stimulate further work along this line. The wide range of soil and climatic conditions as well as in the number of species analyzed make any general conclusions impracticable other than to indicate the need of a great deal of further work on this subject before definite recommendations can be made regarding the probable results under any particular soil type, condition of soil fertility, and geographical location.

If the experimental results ultimately prove generally true on the farm, even if only under certain conditions, the farmer should be specifically informed on all matters pertaining to the agronomic phases of the subject, and if special culture for the crops is necessary, he should be instructed in the details of such culture in order that he may utilize the benefit from the growth of legumes to the fullest possible extent. Farmers for generations have been growing legumes and non-legumes in mixtures but the practice has been restricted by the interpretation of profit in terms of yield, improvement of soil, and increased value of the hay by virtue of its being composed partially of leguminous plants. If the actual percentage of protein in the non-legumes can be increased by associated growth with legumes another possibility is opened up and mixtures heretofore considered unprofitable may prove to be very profitable.

It was from the standpoint of the farmer that the authors undertook to determine whether under ordinary field conditions the growing of clover with timothy, for instance, increases the protein content of the latter and, if so, is this phenomenon true in the case of other legume-non-legume mixtures, whether the plants be annual or perennial. No attempt was made to grow mixtures in specially prepared plots or to determine the cultural history of the fields from which the samples were taken. In each case the samples were obtained from fields of normal fertility and under the conditions typical of the surrounding section. As far as possible samples of standard mixtures were chosen and in all cases they were taken at a stage of maturity when they would ordinarily be cut for hay. Typical plants were selected, whether grown in mixtures or pure culture, and as far as possible in the case of mixtures the samples were procured from areas where the proportions were approximately equal, except in the case of wheat and crimson clover. Spots in the field presenting evidence of abnormally high or low fertility were avoided and every effort was made to have the samples representative of average conditions. To obviate local variation of soil and climate, specimens were collected in different parts of the country. The constituents of each mixture, the protein in the non-legume when grown alone and in mixture, and the increase or decrease in protein in the sample grown in mixture are shown in Table 1.

The following notes indicate the location, soil type, and date of collection of the various sample pairs noted in Table 1.

No. 1. Lanham, Md. Norfolk sandy loam, apparently capable of producing 25 bushels of corn per acre. Sample of rye cut when just coming into head. Samples taken May 21, 1913.

Nos. 2, 7 and 9. Lanham, Md. Norfolk sandy loam underlaid with stiff clay, apparently capable of producing 25 bushels of corn per acre. Samples taken May 18, 1913.

Nos. 3, 5, 6, 11, 18 and 19. Arlington Experimental Farm, Va. Soil originally a stiff infertile clay which during the previous ten years had received repeated crops of rye and legumes to increase its

TABLE 1.—*Showing Effect of Legume on Composition of Non-legume in Mixture.*[4]

Number of Sample Pair.	Non-legume.	Protein in Non-legume.		Increase or Decrease.	Leguminous Constituent of Mixture.
		When Grown Alone, %.	When Grown with Legume, %.		
		%	%	%	
1	Rye hay	10.56	12.58	+2.02	Crimson clover
2	Velvet grass	7.93	9.68	+1.75	Alsike clover
3	Rye hay	5.82	7.38	+1.56	Hairy vetch
4	Rye hay	4.99	6.24	+1.25	Sweet clover
5	Orchard grass	7.66	8.72	+1.06	Alsike clover
6	Sudan grass	6.61	7.66	+1.05	Bonavist bean
7	Tall oat grass	10.16	11.00	+ .84	Alsike clover
8	Sudan grass	6.61	7.30	+ .69	Soy beans
9	Orchard grass	8.13	8.78	+ .65	Alsike clover
10	Rye hay	6.58	6.78	+ .20	Hairy vetch
11	Tall oat grass	9.96	9.83	− .13	Alsike clover
12	Wheat hay	7.43	7.22	− .21	Crimson clover, 75%
13	Sudan grass	6.61	6.40	− .21	Cowpeas
14	Wheat hay	7.43	7.00	− .43	Crimson clover, 25%
15	Redtop grass	7.37	6.81	− .56	Red clover
16	Timothy	7.00	6.40	− .60	Red clover
17	Wheat hay	7.43	6.47	− .96	Crimson clover, 50%
18	Velvet grass	9.48	8.26	−1.22	Alsike clover
19	Wheat hay	8.83	6.22	−2.61	Hairy vetch

fertility, apparently capable of producing 30 bushels of corn per acre. Samples of rye cut when in soft dough stage. Samples taken May 18, 1913.

No. 4. Arlington Experimental Farm, Va. Clay soil, apparently capable of producing 30 bushels of corn per acre. Sample cut when in hard dough stage. Sample taken June 16, 1913.

Nos. 6, 8 and 13. Arlington Experimental Farm, Va. Clay soil, apparently capable of producing 30 bushels of corn per acre. Sample taken October 11, 1913.

No. 10. Lanham, Md. Norfolk sandy loam soil, apparently capable of producing 30 pounds of corn per acre. Sample cut when in soft dough stage. Sample taken May 18, 1913.

Nos. 12, 14 and 17. Georgetown, Del. Rich sandy loam, apparently capable of producing 70 bushels of corn per acre. Samples of wheat cut when in very soft dough stage. Samples taken May 29, 1912.

Nos. 15 and 16. Gallatin, Mo. Good loam soil, apparently capable of producing 50 bushels of corn per acre. Samples taken in summer, 1911.

[4] Analyses in tables 1 and 2 were made by the Bureau of Chemistry, U. S. Dept. of Agriculture.

TABLE 2.—*Showing Percentage of Protein in Crimson Clover and Wheat when Grown Alone and in Mixture.*

No. Sample.	Proportion of Each Crop.	Protein in Clover.	Protein in Wheat.
		per cent.	per cent.
1	Crimson clover, alone	16.41	....
2	" " with 25% wheat	15.75	7.22
3	" " " 50% "	15.65	6.47
4	" " " 75% "	14.31	7.00
5	Wheat, alone	....	7.43

The samples discussed in Table 2 were taken May 20, 1912, near Georgetown, Del., when the wheat was in the very soft dough stage. The soil is a rich, highly fertilized sandy loam, apparently capable of producing 70 bushels of corn per acre. Samples 1 to 5 were all taken from the same field, which showed considerable variation in different portions of the field in the percentages of the two plants present in the mixture.

An examination of Table 2 would indicate that under the particular conditions present not only is the protein content of the wheat slightly reduced by the association with clover but that the percentage of protein in the clover itself is decreased as the proportion of the rye in the mixture increases. This would seem to be in line with Lipman's results[5] where he found that sodium nitrate added to a mixture of oats and peas caused the oats to rob the peas, thereby reducing not only the actual weight of dry matter but sometimes lowering the proportion of nitrogen as well. In the same publication Lipman also states that the presence of a legume in the mixture does not always result in an increased proportion of nitrogen in the dry matter of the non-legume.

It is, of course, impossible to draw any conclusions from the one set of samples herewith presented in Table 2. It may also be stated that the results shown in Table 1, although representing the analyses of a considerable number of legumes and non-legumes taken from three different soil types in different sections of the country, fail to show results from which any general conclusions can be safely drawn as to the probable effect a farmer could expect from this practice. It seems quite clear to the authors of the present paper that the situation calls for much carefully planned experimentation under various conditions of soil fertility, different soil types, and different mixtures in various parts of the country. It is of the utmost importance that the conditions under which this method may be reasonably expected to give markedly beneficial results should be definitely worked out for the benefit of present-day agriculture. The data herewith presented would seem to indicate that the phenomenon of increased protein content in the non-legume by reason of its association with the legume is not so universally true as to make it safe to advocate the method unreservedly as a means of increasing the production of protein upon the farms of this country.

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[5] N. J. Experiment Station Bulletin No. 253.

BRIEFER ARTICLES.

THE COMPOSITION AND QUALITY OF WHEAT GROWN IN MIXTURES WITH OATS.

C. H. BAILEY.

Wheat and oats are frequently grown in mixtures through this section of the northwest, such mixtures being commonly known as "succotash." The millers who finally purchase the mixed grain have varying ideas concerning the quality and milling value of the wheat which it contains. Some are satisfied that the wheat separated from the mixture is lower in gluten and of generally inferior quality to wheat of the same type grown alone. Others state that in their opinion the wheat grown in mixtures with oats is of superior quality. While this difference of opinion may be in part due to dissimilar uses of the term "quality," the disfavor with which this wheat is held by certain millers whose definition of quality is similar to the writer's, led him to undertake the investigations of which this paper is a preliminary report. The work will be continued several seasons before final conclusions are drawn, but the results of the first year's work are at such variance with certain opinions, that it has been deemed advisable to publish them for the information of those who are interested in the matter.

The grain was grown by the Division of Agronomy and Farm Management of this Station. Duplicate series of three plots each were planted. The rate of seeding and the percentage of each grain in the mixture after threshing are shown in Table 1.[1] The control plot was seeded with the usual quantity of wheat, while plots 11 and 24 received one half the usual seeding of both oats and wheat, and plots 12 and 25 received three fourths the usual amount of both grains.

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[1] Data furnished by Professor A. C. Arny, of the Division of Agronomy and Farm Management.

TABLE 1.—*Rate of Seeding and Percentage of Each Grain in the Mixtures Harvested from the Several Plots, Crop of 1913.*

Plot No.	Seeding per Acre.		Grain in Mixture Harvested.	
	Wheat.	Oats.	Wheat.	Oats.
	Pounds	Pounds	Per ct.	Per ct.
10	75	0	100.0	0.
11	37½	32	35.7	64.3
12	56¼	48	39.3	60.7
23	75	0	100.0	0.
24	37½	32	38.8	61.2
25	56¼	48	40.4	59.6

The wheat and oats in the mixtures after harvest were carefully separated, and the clean wheat subjected to chemical analysis, and milling and baking tests. The composition of the wheat is given in Table 2, that of the flour in Table 3, and the milling and baking tests in Table 4.

The milling of the wheat samples in the experimental mill and the baking tests of the flour were made by the methods usual to this laboratory, a description of which may be found in Minnesota Agricultural Experiment Station bulletins Nos. 131 and 143.

The percentages of the several constituents are calculated to a moisture-free basis in all cases. In general the differences in composition between the grain from the several plots are relatively slight. The one exception is the wheat from plot 25, which contains a lower percentage of crude protein than do the other samples from the same series. The differences in the baking qualities of the flours produced are less great, however, these being practically the same in all cases. Moreover the appearance of the three wheat samples from each series is very similar, no tendency toward softness, or the "yellow-berry" condition being indicated in any of the samples. The differences between the samples in any one series is no greater in any regard than those between the two control plots of wheat (Nos. 10 and 23) and in most instances are even less.

TABLE 2.—*Composition of the Wheat Grown Alone and in Mixtures with Oats*

Plot No.	Moisture.	Moisture-free Basis.				
		Crude Protein ($N \times 5.7$).	Ether Extract.	Crude Fiber.	Ash.	Nitrogen-free Extract.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
10	10.31	13.48	2.61	2.62	2.18	79.11
11	10.46	13.83	2.69	2.65	2.18	78.65
12	10.05	13.25	2.66	2.48	2.16	79.45
23	10.60	14.19	2.47	2.54	2.24	78.56
24	9.90	14.15	2.70	2.64	2.23	78.28
25	10.50	13.45	2.72	2.52	2.22	79.09

TABLE 3.—*Composition of the Flour Produced in the Experimental Mill from the Wheat Samples.*

Plot No.	Moisture.	Moisture-free Basis.					
		Crude Protein ($N \times 5.7$).	Ash.	Gluten Nitrogen.	Non-gluten Nitrogen.	Total Nitrogen as	
						Gluten.	Non-gluten.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
10	10.09	12.01	0.59	1.668	0.439	79.4	20.8
11	10.07	11.81	.57	1.623	.447	78.4	21.6
12	10.13	12.12	.56	1.682	.444	79.1	20.9
23	9.99	13.50	.56	1.914	.454	80.8	19.2
24	10.05	13.42	.59	1.897	.459	80.5	19.5
25	10.09	12.49	.56	1.742	.448	79.5	20.5

TABLE 4.—*Results of the Milling and Baking Tests of the Wheat Samples.*

Plot No.	Total Flour.	Tests of the Middlings Flour.		
		Volume of Loaf.	Water Used.	Color Score.
	Per ct.	Cc.	Per ct.	
10	72.9	2,510	62.4	100
11	72.6	2,500	61.5	100
12	72.6	2,490	62.1	100
23	72.9	2,510	64.7	99
24	72.3	2,500	63.8	99
25	72.5	2,530	64.7	98

SUMMARY.

The wheat grown in mixtures with oats did not vary in composition and quality from that grown alone. The flour milled from such wheat contained practically the same percentage of crude protein and gluten, and exhibits nearly the same baking strength. The slight variations in these properties which were found, are no greater than were found in duplicate samples from adjacent plots of wheat treated identically alike.—Agricultural Experiment Station, St. Paul, Minn.

WINTER BARLEY IN MICHIGAN.

FRANK A. SPRAGG.

Until now, winter barley has not been a success north of the Ohio River as all previously existing varieties were killed by hard winters. The Michigan Experiment Station has three winter barleys that successfully passed the severe winter of 1911–12. All are pedigreed strains from the Office of Cereal Investigations of the U. S. Department of Agriculture. One of these is being increased at the

Upper Peninsula Station at Chatham. It has done well there, and this fact seems to indicate that these winter barleys may extend the winter barley belt to Lake Superior.

The two strains that were increased at East Lansing in 1914 were ripe on June 24th, or three weeks earlier than the earliest spring barley. During the seasons of 1913 and 1914 these two strains have averaged 55.4 bushels. The average yield of barley in Michigan is set at 25 bushels by the U. S. Department of Agriculture. If generally grown, these winter barleys may double the average yield of barley in the State. Compared with oats on the basis of pounds of grain per acre, 55.4 bushels of barley equals 83.1 bushels of oats.—Michigan Experiment Station, East Lansing.

AGRONOMIC AFFAIRS.

THE THEORY OF FACTORS IN CROP PRODUCTION.

The trend of agronomy, as reflected by the lectures given at Columbia, Missouri, during the session of the Graduate School of Agriculture, is increasingly in the direction of determining as accurately as possible the response of each crop plant to each factor of its environment as far as it is possible to control these factors. The fundamental idea is that crop production is dependent on the interplay of numerous factors or environmental conditions as regards soil, climate, methods of culture, and the inherent peculiarities of the plant itself. For convenience it may be denominated the theory of factors in crop production. Special phases of this theory are familiar in the less broad theories known as the law of the minimum and the theory of limiting factors.

The law of the minimum has been used mainly in the discussion of the supply of chemical soil constituents as the absence in the soil of any such vital substance as nitrogen, phosphorous or potash necessarily limits growth to the supply contained in the seed or the clon. As a corollary any further growth is limited by the amount of the element available in the smallest quantity, no matter how abundant the other necessary elements may be.

The theory of limiting factors has been discussed principally in studies relating to the varying behavior of the same species of plant under different climatic conditions.

Notwithstanding that the idea of separate factors has long been recognized in studies of plant growth, but few comprehensive studies have ever been made with the idea of determining accurately the behavior of any crop plant, as respects yield, to any one factor of its environment. With a rough approximation to accuracy, we know the behavior of many crop plants to extreme conditions of cold, heat, humidity, soil moisture, alkali salts, etc. In fact, the area of the successful culture of any plant affords an approximation to the conditions the plant demands. These conditions are much more accurately known in the case of greenhouse crops than in that of field crops, but even in the former case the knowledge is the result of experience rather than of accurately conducted investigation.

There are on record many results of investigations by plant physiologists covering the reaction of a plant, especially seedlings to a single varying factor. It is, of course, impossible to vary any one factor without affecting others, still the results have added much to our knowledge of the subject. None of these investigations has, however, been conducted with the end in view of greatest interest to agronomists, namely, the effects on yield and quality of the crop.

So far as such investigations have been conducted, whether in reference to nutrient salts, to soil water or to such physical factors as heat and light, the results when plotted on a curve, show much the same type of effects. With a nutrient salt, for example, the growth as indicated by a series of cultures increases very rapidly with additional supplies up to a certain point and thereafter but slowly until an excessive amount of the salt is used, when the growth is quickly and disastrously affected. Theoretically, the optimum or best condition of any factor is represented by the point of greatest curvature in the plotted results. Usually this point indicates the most profitable amount of a nutrient to use, as above it the increased returns become proportionally smaller and smaller. The optimum amount of any nutrient is, however, known to be affected by other factors, such as the water content of the soil, and other salts present. The actual determination of the optima for each factor that affects yield and quality, both when used alone and in combination with other varying factors, will require a stupendous amount of investigation.

Nevertheless, it now seems that the further progress of agronomy demands just such far-reaching investigations. To carry them out will require especially equipped greenhouses where each factor can be controlled as accurately as possible, and the choice of one or more crops best adapted to such conditions of culture. The first choice would apparently lie among such intensively grown greenhouse crops as lettuce or tomatoes because our empirical knowledge of these is greatest and because the results would be of undoubted economic value. While the crops are technically horticultural the problems are fundamentally agronomic. It is not too much to anticipate that such a great body of results, in which the results are determined for all important factors and combinations of factors, would throw great light on the numerous obscure phenomena that occur in nearly every field experiment.

The subject is one of fundamental interest to every student of crop production, regardless of the plant chosen for investigation. It is a line of research for which there is crying demand and which should be jointly supported if necessary by all crop specialists. Such broad knowledge of the physiology of a single crop plant would open up lines of attack on the numerous problems that confront every agronomist.

One other consideration also adds to the need of such far-reaching investigations. The *practical* field culture of most crops and for most places has along conventional lines been developed to a high degree. The *theoretical* basis of our empirically reached practice is still very obscure and very unsatisfactory. A broader and more accurate series of investigations than has yet been conducted is necessary if much of our agronomy is ever to be truly scientific.—C. V. P.

DOCTORATES CONFERRED IN 1914.

The issue of Science for August 21 contains an interesting article on doctorates of philosophy conferred by American Universities. A grand total of 502 is recorded of which 241 were given in the sciences. Of this number 9 were in agriculture and 34 in botany. In the last 17 years 62 degrees have been granted in agriculture and 275 in botany. Below are the subjects of eleven theses of interest to agronomists, with names of the authors and of the university conferring the degree.

A Comparative Study of the Effect of Cumarin and Vanilin on Wheat Grown in Soil, Sand and Water Cultures. Jehiel Davidson. (Cornell.)

A Physiological Study of the Germination of *Avena fatua*. Winfred McKenzie Atwood. (Chicago.)

Evaporation and Soil Moisture in Relation to the Succession of Plant Association. George Damon Fuller. (Chicago.)

Some Effects of Ethylene on the Metabolism of Plants. Edward Maris Harvey. (Chicago.)

The Effect of Kerosene and other Petroleum Oils on the Viability and Growth of *Zea mais*. John Hamilton Whitten. (Illinois.)

A Study of the Non-protein Form of Nitrogen in Alfalfa. Ralph Howard Carr. (Wisconsin.)

Damping off and Root Decay of Sugar Beets. Howard Austin Edson. (Wisconsin.)

The Helminthosporium Diseases of Barley. Aaron Guy Johnson. (Wisconsin.)

Some Distinctions in Our Cultivated Barleys with Reference to their Use in Plant Breeding. Harry Vaughn Harlan. (Minnesota.)

The Killing of Plant Tissue by Low Temperature. William Henry Chandler. (Missouri.)

On the Uses of Plants by the Indians of the Nebraska Region. Melvin Randolph Gilmore. (Nebraska.)

NOTES AND NEWS.

Lyman Carrier, formerly agronomist of the Virginia College and Station, has been appointed agronomist in charge of pasture investigations in the office of forage crop investigations, U. S. Bureau of Plant Industry.

J. Allen Clark, scientific assistant in charge of the cooperative cereal experiments of the U. S. office of cereal investigations and the North Dakota Station at the Dickinson Substation was made scientific assistant in western wheat investigations, U. S. office of cereal investigations, on July 1, with headquarters in Washington.

O. W. Dynes, associate agriculturist in farm crops and plant breeding at the North Dakota College and Station, has accepted a scholarship in the department of plant breeding at Cornell University where he will continue work for an advanced degree.

H. K. Hayes, plant breeder of the Connecticut Station, has accepted the position of associate agriculturist in plant breeding at the Minnesota College and Station.

T. B. Hutcheson has resigned the position of associate agriculturist in plant breeding at the Minnesota College and Station on August 31 to become agronomist of the Virginia College and Station, where he was formerly assistant agronomist.

F. L. Kennard, agronomist of the Idaho College and Station, has accepted the position of agronomist at the Northwest Substation of the Minnesota Station at Crookston, Minn., where he will have charge of field experiments and the teaching of agronomy in the winter school of agriculture.

C. K. McClelland, formerly agronomist of the Hawaii Station, has become agronomist of the Georgia Station at Experiment.

J. M. Westgate, agronomist in charge of clover investigations in the office of forage crop investigations, U. S. Bureau of Plant Industry, will become agronomist in charge of the Hawaii Station about January 1, 1915, vice E. V. Wilcox, who returns to Washington to a position in the Office of Experiment Stations in connection with its inspection of the work and expenditures of the State experiment stations.

C. V. Piper, agrostologist in charge of forage crop investigations in the U. S. Bureau of Plant Industry and president of this Society, is the author of a 600-page volume in the Rural Text-book series, entitled "Forage Plants and their Culture."

W. P. Kelley, chemist of the Hawaii Station, has resigned to accept the position of agricultural chemist in the University of California, with headquarters at the Citrus Station at Riverside.

O. I. Bergh, for several years instructor in agronomy at the Crookston (Minn.) school of agriculture, has been appointed superintendent of the Grand Rapids (Minn.) experiment substation.

C. P. Bull, who was granted leave for one year to act as secretary of the National Corn Exposition, has resumed his duties at the Minnesota College of Agriculture.

Alex Carlyle, assistant in plant breeding at the Minnesota Station, has accepted the superintendency of the experiment farm established in connection with the new provincial school of agriculture at Vermillion, Saskatchewan, Canada.

W. L. Carlyle, dean of agriculture in the Idaho College and director of the Station, and J. F. Nicholson, vice director of the Station, and bacteriologist of the College and Station, have resigned.

R. E. Karper, assistant in cereal investigations in the Kansas Branch Station at Hays, and Adrian Daane, a graduate and post graduate in agronomy of Wisconsin University, have been appointed assistant agronomists in the Oklahoma College and Station, succeeding E. E. Hall, and H. H. Wright, who have resigned to engage, respectively, in county demonstration work in South Carolina, and graduate study in Wisconsin University.

A. G. McCall, agronomist of Ohio University, has taken leave of absence for a year, beginning in September, and will pursue graduate study in soil physics and related subjects at Johns Hopkins University.

George Livingston, who has been studying crop conditions in Europe during the past summer, will be acting head of the department of agronomy at Ohio University during the absence of Professor McCall.

Clark S. Wheeler, assistant in agricultural extension in Ohio University, has been placed in charge of the extension work in public schools, in place of A. B. Graham, resigned.

O. O. Churchill remains head of the department of agronomy in the Oklahoma College and Station. The report of the action of the board of regents as recorded in the last issue of the Journal, was entirely erroneous, so far as it related to Professor Churchill, and this correction is gladly made.

Robert O. Suddath, of the Georgia College, has accepted a position as agent of the farmers' cooperative demonstration work, at Albemarle, N. C.

Satyasaran Sinha has been appointed professor of botany at Berhampore College, Berhampore, Bengal, India.

E. L. Hsieh is technical expert to the Ministry of Agriculture and Commerce, Republic of China, and is located at Peking.

Malon Yoder, in charge of field crops in the department of agronomy at Ohio University, has been appointed assistant in grain standardization in the U. S. Bureau of Plant Industry and is stationed at the newly established laboratory at Portland, Oregon.

Frank App, has resigned as assistant agronomist of the New Hampshire College and Station to accept a similar position in the New Jersey College and Station.

F. D. Farrell, agronomist in the U. S. bureau of plant industry, has been placed in charge of the recently established office of Demonstrations on Reclamation Projects. This office will have charge of the demonstration work to be done by the Department of Agriculture on the government irrigation projects in the west. This work will be directed chiefly toward the establishment, on a community basis, of various agricultural industries, notably, horticulture, the production of special irrigated field crops, dairying, swine production, and other animal industries.

APPROPRIATION OF THE U. S. DEPARTMENT OF AGRICULTURE.

In the Appropriation Act, providing for the expenses of the Federal Department of Agriculture in the current fiscal year, beginning July 1, 1914, a total amount of $19,865,832 is carried. This is an increase of nearly two million dollars over the year before but the actual increase of funds is less than this because of circumstances noted below. The appropriation for the Bureau of Plant Industry is $3,616,045, which is an apparent increase of $948,050. However, $300,000 of this is appropriated in lieu of an equal amount formerly contributed by the general education board for demonstration work in the South, to which contribution objection was made in Congress. The remaining increase is distributed in small amounts throughout the Bureau.

The appropriation for the Office of Markets is increased from $50,000 to $200,000.

To encourage and aid in the agricultural development of the Government reclamation projects and to assist the settlers on the projects through demonstrations, etc., a new appropriation of $40,000 is made.

New Books.

Forage Plants and their Culture. By Charles V. Piper, M.S., Agrostologist in Charge of Forage Crop Investigations, U. S. Department of Agriculture. The Macmillan Co., New York. 1914. Pp. v + 618.

The aim of the author, as stated in the preface, "has been to present as concisely as practicable the present state of our knowledge with reference to each forage crop grown in America." In scope the work is much more complete than other books pertaining to the subject. It is intended primarily as a text-book for agricultural colleges.

The early chapters of the book are devoted to such general phases of the subject as preservation of forage, choice of forage crops, seeds and seeding, meadows and pastures, and the statistics of forage crops. The remaining chapters deal with specific forage plants with at least a brief treatment of the most unimportant. The author emphasizes the fact that the agronomic knowledge of no one of the numerous forage plants is as extensive as that of the small grains, corn, cotton, potatoes or tobacco.

The treatment of each forage crop is divided into numerous appropriate subheadings, in each of which the principal experimental work bearing on the subject is cited, even if, as is sometimes the case, the reported results are contradictory. In this way the need of further investigation is often clearly indicated.

The forage crop problem for the whole of America is complex owing to the wide diversity of climatic conditions. No less than 114 different forages are discussed, of which 45 are grasses, 54 legumes, and 15 miscellaneous plants of other botanical families. Not one of these plants is cultivated over the whole area and many of them are grown in a comparatively small restricted region.

In the discussion of feeding values in the chapter entitled "Choice of Forage Crops," Professor Piper clearly indicates that he has but little confidence in results other than those based on adequate feeding trials, and these have been carried out in a comparative way for but few American hay plants. He states that "Chemical analyses can in no sense replace feeding experiments in determining feeding values. With a new forage plant a chemical analysis can throw no light on palatability, digestibility or physiological effects."

Taken as a whole, the book should stimulate a much more critical attitude towards forage crop problems. It is an important contribution to the agricultural literature of the day, presenting as it does a well rounded viewpoint of the whole status of forage crops in the United States and Canada.

Professor Piper has rendered a service to all American agronomists in bringing together in a critical way the enormous amount of scattered data related to American forage plants. The book should prove exceedingly helpful to all teachers of agronomy. The illustrations consist of seven page plates and 62 text-figures.

MEMBERSHIP CHANGES.

The membership of 380, reported in the last issue, plus 8 new members and 2 reinstated members, and less 1 member resigned and 1 lapsed, places the present membership at 388. From past experience it seems certain that the membership will yet exceed 400 during the year 1914.

NEW MEMBERS.

APP, FRANK, Rutgers College, New Brunswick, N. J.
HYSLOP, GEO. R., Agricultural College, Corvallis, Ore.
KENNARD, F. L., Northwest Substation, Crookston, Minn.
MCCLELLAND, C. K., Experiment Station, Experiment, Ga.
MCINTIRE, W. H., Experiment Station, Knoxville, Tenn.
MYER, D. S., Experiment Station, Lexington, Ky.
SMITH, RALPH W., Dickinson Substation, Dickinson, N. Dak.
VOORHEES, JOHN H., Experiment Station, New Brunswick, N. J.

MEMBERS REINSTATED.

T. F. HUNT, A. G. MCCALL,

MEMBERS RESIGNED.

TEN EYCK, A. M.

MEMBERS LAPSED.

W. D. GRIGGS (omitted from May-June issue.)

Addresses Changed.

Bergh, Otto I., Experiment Station, Grand Rapids, Minn.
Bouyoucos, G. J., Experiment Station, East Lansing, Mich.
Buell, T. W., Experiment Substation, Krum, Texas.
Bull, C. P., Experiment Station, University Farm, St. Paul, Minn.
Carlyle, Alex., Experiment Farm, Vermillion, Sask., Canada.
Carrier, Lyman, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Chilcott, E. F., Woodward Field Station, Woodward, Okla.
Clark, J. Allen, Bur. Plant. Indus., U. S. Dept. Agr., Washington, D. C.
Delwiche, E. J., 1221 Chicago Street, Green Bay, Wis.
Dynes, O. W., 205 Fairmount Avenue, Ithaca, New York.
Fletcher, S. W., 10 Pine St., Takoma Park, D. C.
Hayes, Herbert K., Experiment Station, University Farm, St. Paul, Minn.
Karraker, P. E., Agricultural College, Lexington, Ky.
Kelley, W. P., Citrus Experiment Station, Riverside, Calif.
Peters, David C., The Christian Church, Honolulu, Hawaii.
Sinha, Satyasaran, Berhampore College, Berhampore, Bengal, India.
Suddath, R. O., Farmers' Cooperative Demonstration Work, Albemarle, N. C.
Wyatt, F. A., 708 S. 4th Street, Champaign, Ill.
Yoder, Malon, 310 Worcester Building, Portland, Oregon.

COMING EVENTS.

Under this caption it is proposed to keep a standing schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

American Society of Agronomy.

Annual Meeting, Washington, D. C., November 9–10, 1914.

American Association for the Advancement of Science.

Philadelphia, Pa., Convocation Week, 1914–15.

American Society of Agricultural Engineers.

Annual Meeting, Chicago, December 28–30, 1914.

American Society of Milling and Baking Technologists.

Annual Meeting, Washington, D. C., November, 1914 (in connection with the Association of Official Agricultural Chemists).

Association of Official Agricultural Chemists.

Annual Meeting, Washington, D. C., November 16–18, 1914.

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FUNDAMENTAL PRINCIPLES IN AGRONOMY.

C. V. PIPER.

U. S. DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

(*Presidential address before the American Society of Agronomy, November 10, 1914.*)

The phrase "principles of agriculture," or a verbal equivalent of the same, is one that has frequently been used by writers interested in the advancement of agriculture. The search for or the elucidation of these principles has often been urged as the highest function of the agricultural investigator. Curiously enough no one seems ever to have pointed out just what is meant by a general or fundamental principle in agriculture. Nor has any one enumerated as such those already known or accepted. It is true that more than one book bears some such title as "Principles of Agriculture," but upon examination one is quickly convinced that the title is merely a euphonious label.

Inasmuch as no one has attempted to enumerate in a list the principles of agriculture, there exists doubt as to just what these principles may be. Not that there is obscurity to the meaning of either the word "principals" or the word "agriculture,"—but that there is much haziness as to which generalizations may properly be called principles of agriculture. It is, of course, important that these be well recognized if it be true that the highest function of the investigator is to establish or to elucidate such principles.

In this effort to enumerate what the writer regards as principles or fundamental generalizations, the scope is limited to the plant side of the subject; that is, crop production. In attempting to formulate such a list of generalizations, various questions arise, such as their relative importance and the sufficiency of evidence as to the validity of each. More striking, perhaps, is the fact that nearly all such generalizations, to be true, must needs be stated so broadly that except for pedagogical purposes, it is difficult to see wherein they possess much value. If, however, we are to continue to refer to principles or fundamental problems of agriculture, we ought to reach some agreement as to what is meant in terms more concrete than are commonly used.

After some consideration I have been able to formulate 18 such generalizations that appear to me to possess fundamental importance. They are, however, of very unequal values, viewed either from the theoretical or the practical standpoint. Some of them are very simple and essentially axiomatic. I must confess that doubt exists in my mind as to whether all of these generalizations can properly be called principles, and I shall not be surprised if there is wide divergence of judgment from the list I propose to present and briefly to discuss. I may add that there is nothing logical in the sequence in which they are presented, as most of these generalizations bear little relation to each other.

1. EVERY CROP PLANT HAS A DEFINITE RANGE OF ADAPTATIONS OR REACTIONS AS REGARDS CLIMATE (TEMPERATURE, MOISTURE, LIGHT) AND SOIL (MOISTURE, TEXTURE, BIOLOGY, CHEMICAL CONTENT.)

Broadly speaking, every crop plant is grown under conditions approximating those in which it occurred originally. We are forced to assume that every crop grown by primitive man, and that includes every one of our important food crops, was first cultivated in or near the region where it grew wild. Annual plants of tropical origin (corn, beans, tobacco, sorghum) are cultivated with great success as summer crops in temperate regions, but this is due purely to the fact that short-season varieties have been developed which mature under conditions not unlike those of their native habitat.

Conversely, temperate annuals (lettuce, radish, peas, oats) are readily grown during the cool season in the tropics and subtropics. In the case of perennials, however, such possibilities do not exist or at least to a very limited degree. Most perennials from frostless regions are promptly killed when the temperature falls to the freezing point.

Conversely, temperate trees taken to frostless regions, even to the so-called temperate climate of mountains in the tropics, behave in a most abnormal fashion, probably due to the fact that they are denied the period of winter rest to which they are adapted. No single example exists in agriculture of a temperate-zone perennial whose culture has been successfully introduced into a frostless region. Indeed, the southern limit of the successful culture of such plants as the apple, cherry and plum falls far short of the frostless line. Conversely there is no example of a tropical perennial whose culture has been successfully extended into a region where winter freezes are normal. There can be little question that in perennial species of wide geographic range, those from the coldest extremes are most resistant to cold. This fact has indeed long been recognized as of practical value. It is still, however, unproven that any perennial can be modified to withstand a greater degree of cold than any of its immediate congeners. As to the heat factor or the lack-of-cold factor, the problem is less precise, as individuals will continue to exist even where they are unable to produce fruit. From a purely botanical standpoint the evidence of the extreme slowness of change in adaptations is no less convincing. Botanists know of no single case where a perennial plant has naturally extended its range either northward or southward in historical times.

These reactions of plants to heat and cold are mentioned merely to emphasize the extreme delicacy of plant adaptations, always most clearly shown at or near the extreme points of their natural range or of their artificial culture. Why a mango tree is killed by a light freeze while an apple or a magnolia is uninjured is still an absolute mystery. All we can record regarding adaptations are the actual facts. As yet there is no theory of adaptation worthy the name of theory.

The phrase "definite range of reactions" needs some explanation. In all cases where the reactions of a plant have been studied in reference to a single varying factor (such as heat, nutrient salts, moisture), a point is finally reached where an increase of this factor results more or less sharply in injury to the plant and beyond, but near these points, in death. The two extreme or critical points are the maximum and minimum points of the particular plant in reference to that factor. The optimum is less easily definable, but from an economic crop-production standpoint, at least, may be considered that point beyond which the increased crop return is not profitable. If the increases in yield due to the factor in question are plotted in a curve, the optimum is at or near the point of greatest curvature. Beyond this point increments to the yield becomes very small in accordance with the law of diminishing returns.

It may be questioned whether or not what I am here discussing is one of the general principles of crop production. In my opinion it is the most fundamental and the one on which least critical work has thus far been prosecuted. There is need of an exact knowledge of the reactions of every important crop plant to every environmental factor—temperature, moisture, light, fertilizers, etc.—each studied alone and also with reference to every other factor. Such work can be prosecuted only in specially equipped greenhouses. With the data that such research will provide, it will probably become possible to interpret many of the very puzzling results obtained in field-plot experiments. In my judgment, in no other field is agronomic research now so much needed.

2. TILLAGE TENDS TO INCREASE YIELDS.

Tillage of some sort is necessarily as old as crop cultivation, even if the tillage were no more than the making of a hole in which to place the seed.

Theories of tillage are many and there are no adequate data to determine how much yield is affected by any one of the various factors postulated. In nature, such tillage as occurs is the work of roots, of frost, of worms and other burrowing animals, of washing, and of landslides. Perhaps the more luxuriant growth of plants on landslides and about ant hills may have first put the idea of tillage in the mind of the savage.

Agricultural writers base theories of tillage on various factors; namely, the destruction of weeds, the burying of vegetable matter, the better control of soil moisture and soil temperature, and especially the loosening and compacting of soil to influence aeration.

There is a lack of adequate critical investigations bearing on most of these theories. Recent investigations by Cates and others tend to show that control of the weed factor is probably the main function of tillage.

3. SHALLOW TILLAGE CONSERVES SOIL MOISTURE.

The theory of the dust mulch to conserve soil moisture has long been considered fundamental in dryland agriculture and, being supported by apparently adequate laboratory data, has been generally accepted as valid. Recent field investigations, however, have cast serious doubt on the efficiency of the dust mulch to prevent evaporation of soil moisture. The dust-mulch system of tillage has long been practiced over wide areas of dry-farmed land with very satisfactory results. The doubt that is now cast on dust-mulch tillage from the standpoint of soil moisture does not preclude its being justified on other grounds.

4. Rate of seeding or distance of spacing affects yield.

In rate of seeding there can not be said to exist either minimum or maximum rates. The only rates of importance are the optimum and those approaching the same. While very numerous field experiments have been conducted at many experiment stations to determine the best rates of seeding for each crop, these studies have for the most part been frankly empirical, the best rate of seeding being, of course, that which gave the largest return, regardless of what other factors were involved. In agronomic practice the tendency lies in the direction of heavy seeding, at least with broadcast or drilled crops. A reduction in yield from too heavy seeding is rarely serious. In perennials like timothy, alfalfa and clover, too heavy seeding is remedied by crowding and consequent mortality of a large proportion of the individuals. Indeed, heavy seeding with these crops is the rule, as in weedy ground it is better to have the space occupied by surplus plants of the kind desired than by weeds.

In annuals this does not apply, as too thick planting of small grains may show reduced yield. Such plants nearly always compensate against thin seeding by stooling. Very heavy seeding is rarely practiced owing to the cost of the seed, but the best brewers' barley is said to be grown where the seed is planted at the rate of 4 bushels to the acre. This results in a crop of plants each producing a single head, so that the crop ripens evenly, which is not the case where the plant stools.

In the cases of plants grown in broad rows or in hills, such as corn, potatoes, etc., there are no comprehensive experiments recorded to determine the best rate of planting. With such crops, the requirements of farm machinery for cultivating have nearly always determined the narrowest width of the rows or of the hills. Even should it be shown that under given conditions corn plants grown in hills 1 foot or 2 feet apart each way should give the greatest yield per acre, the results would be of no immediately practical value.

The fact remains, however, that with our best known crop no one has determined, for any locality, the distance of spacing that will give the greatest yield. With a crop where the weed factor can readily be controlled such results might be of much theoretical interest even if not of practical value.

Among the most comprehensive experiments of this sort have been those of Wood with rice at Coimbatore, India. Where rice seedlings are transplanted and hand weeded, as is commonly the case in the Orient, the best degree of spacing is of obvious importance, affecting as it does the cost of seed, of planting, and of weeding, as well as the amount of return secured. This piece of work is one of very few which has resulted in a change of practice among the natives, strangely enough the saving in the cost of seed and not the increased yield being the factor that was most potent in influencing them to change.

5. DEPTH OF PLANTING AFFECTS STAND AND THEREFORE MAY AFFECT YIELD.

This principle is one of minor importance, as it is necessary only to guard against too deep planting, in which case the seedlings may not reach the surface,—or too shallow planting, in which event a large percentage may be destroyed.

In nature most seeds become placed on or very near the surface, with a consequent high mortality. In agriculture, the failure to secure a good stand is seldom due to too deep or too shallow seeding alone.

6. TIME OF SEEDING AFFECTS YIELD.

Time of seeding often bears an important relation to the subsequent yield, and numerous field experiments bearing on this subject are recorded. The best time for seeding must be determined empirically for each plant and for each locality, but there is often a very definite correlation between the adaptations of the plant and the best time of seeding.

7. QUALITY OF SEED AFFECTS YIELD.

Few generalizations of agriculture have been surrounded with as much doubt as that of the relation of quality of seed to resultant yield. Quality is a broad characteristic and the term covers such diverse factors as size, weight, plumpness, color, age, and source. It is generally believed that large, heavy, plump seeds will give better yields than will small, light or shrivelled seeds. There is scarcely room for doubt that the former produce stronger seedings than the latter. When, however, it comes to field sowings where, as is commonly the case, many seeds are sown for each plant that matures, it is by no means clear that good seed insures a better yield.

Montgomery has compiled the American experimental data as far as small grain crops are concerned. On the whole they show a slightly higher yield for the better seed but the methods of conducting the experiments have been so diverse that there is still much room for doubt as to which of the characteristics included in "quality" are really important.

In the case of corn, viability has been the point considered most important, as any lack of germination reduces the percentage of stand. Hartley has clearly shown that variation in viability is primarily due to the curing of the seed and not to an inherent character, as had been supposed.

Webber's results with cotton showed a better yield from large seeds, but this work seems not to have been repeated nor the idea to have become adopted in practice.

Shamel secured better plants with heavy seeds of tobacco than with light seeds. Later investigations have not confirmed these results.

Experiments with cowpeas have given no better yields from large seeds than from small seeds of the same variety.

With grasses and clovers but few experiments are recorded. Most of these show yields slightly in favor of heavy seed.

The total amount of data recorded on the subject is yet far from adequate and the problem still affords a wide field for further investigations.

Somewhat different in character is the matter of source of seed. Very extensive work of this sort has been carried out with grasses and clovers in European countries, especially Germany and Switzerland, as much of the seed there used is imported. Inasmuch as the same kind of seed can frequently be secured from several different countries, the relative producing value of each becomes a matter of importance. The most striking result of these numerous trials is the large proportion of cases in which locally grown seed gave the best returns. From biological considerations this is just what should be expected, as the locally grown plant has become adapted to the conditions.

The same phenomenon is seen in the eastern states in the marked inferiority of alfalfa grown from Turkestan seed and that from American seed, a difference which occurs nearly everywhere in the region named. In the drier regions the difference is sometimes in favor of the Turkestan, especially if the American seed be from irrigated land.

Most of the changes that thus take place by which a plant becomes adapted to its environment are undoubtedly brought about by a process of elimination. On the other hand there are some fairly clear cases of a plant varying *en masse* in a new environment—for example, Cook's Guatemala cotton becoming earlier and more fruitful in Texas; the tendency of some varieties of soy beans to become earlier or later, depending on whether they are grown northward or southward; and the generally accepted statement that northern varieties of corn tend to become later when grown southward.

A corollary to the generalization here discussed might thus be worded:

Locally grown seed tends to give better yields than seed of the same sort brought from a distance.

To some, the marked exception of the potato will at once occur, as there can scarcely be question of the superiority of northern seed over local seed southward. But the potato tuber is not technically a seed, and besides we are as yet wholly in the dark as to why the northern tubers do give better results.

8. Rotative cropping tends to increase or to maintain yields. Single cropping tends to reduce yields.

These are complementary statements of the same general principle, which is commonly accepted as valid. Explanations of the phenomenon are, however, purely theoretical, except where legumes enter into the rotation. Theoretical explanations center about (1) differing nutrition requirements of different crops; (2) accumulation of toxic by-products; (3) insurance against diseases and insects.

Few principles in agriculture have been accepted longer than has that of rotation, but there is still a dearth of experimental data to determine the benefits quantitatively or of critical investigations in reference to the theoretical explanations advanced.

The subject is one which has been almost inextricably involved with theories of soil fertility, though in many of its phases this is not at all necessitated. An evident reason why critical investigations of the theories of rotation have not been prosecuted is the fact that such require a long time and also great expense to obviate the disturbing factor of soil variability.

9. Mixed seedings tend to increase yields.

It has long been accepted as a fact in Europe that mixtures of the small grains will return a greater yield of seed than any one of them. Such maslin crops are seldom grown in America.

Mixed seedings for forage are commonly grown in the United States, but such usually contain a legume and thereby another factor becomes introduced. It is commonly believed that mixed seedings of grasses give a better yield of hay than pure cultures and this is substantiated by the limited number of quantitative data that have been recorded.

The explanations that have been advanced to account for better yields from mixed perennial seedings not containing legumes are all theoretical and not one can be considered proven. These theories involve such explanations as (1) different nutrition requirements; (2) differing root habits; (3) differing seasonal adaptations; (4) differing light requirements in mixtures of tall and short plants; and (5) the lessening of danger from insects and disease, and the compensating growth of the other species in case any one is injured or destroyed.

In India the plantings of the natives are invariably mixed, two, three or four different crops being planted together. Usually one of these is a legume, but mixtures of non-legumes are frequent. Some of these mixtures are as follows: Sorghum and rice; sorghum, mung bean, and castor beans; sorghum and cotton; peppers and cotton; sorghum and a legume; pearl millet and a legume; rice, pigeon peas and castor beans.

The belief prevails that such mixtures give greater returns than pure plantings of each in equivalent area. Some European observers believe that this increase is mainly due to the reduced danger to each crop in the mixture from insects and disease, and the compensating fact that if one crop be thus destroyed the other plants are there to take advantage of the room thus vacated.

The different plants in these mixtures often mature at different times and are then separately harvested—a process practicable only where labor is very cheap.

While the use of the mixed seedings in America is largely limited to forage plants, the agronomic problems involved are of interest and the subject is worthy of careful study. Incidentally it may be pointed out that only mixed growths commonly occur in nature. Pure natural growths are seldom found except in special environments.

10. FERTILIZERS (NEARLY ALL COMMON SUBSTANCES) TEND TO INCREASE YIELDS.

In modern times perhaps more investigations have been devoted to fertilizers than to all other phases of agriculture and certainly more pages have been written on this subject than on any other pertaining to crop production. It is certain that no other agricultural topic has involved so much controversy as the nature and function of fertilizers. This may indeed be counted gain as the discussion has served to stimulate renewed investigations.

Like so many other problems in agriculture the different theories proposed are by no means mutually exclusive. Indeed there is no sufficient reason to deny that there is some measure of truth in each of them.

The plant-food theory of fertilizers for which Liebig stands as the dominant dynamic force followed fast upon the discovery of the essential elements of plant nutrition. This theory and its corollaries have been the burden of discussion in most text books of agricultural chemistry and of scientific agriculture. On it is based the entire fertilizer industry and the potent influence fertilizers have exercised in modern agriculture. There is not much difference of judgment regarding the value of fertilizers, but there is wide divergence of opinion as to the nature of their action. According to the point of view, they may function (1) as direct elements of nutrition; (2) as indirect preparers of available nutrients; (3) as stimulants; or (4) as destroyers of toxic substances.

Of a different nature are the theories that would ascribe the reduced yields from long-cropped soils as due in part, at least, either (5) to the accumulation of various injurious fungi in the soil or (6) of protozoans which seriously reduce the number of beneficial soil bacteria.

Most of the discussion of the function of fertilizers has been of a polemical nature, the facts being marshalled by advocates of one or another theory of their action.

It is quite obvious that increased growth or increased yields might result from any one of the causes postulated. There is nothing to prove that each one of the actions may not occur in particular cases. Indeed, the evidence thus far accumulated makes it seem highly probable that there is some truth in each of the theories; that the action of fertilizing substances may be fundamentally distinct in different cases.

One source of difficulty in interpreting experiments of a critical nature is our meager knowledge concerning the actual means by which plants absorb substances and the fundamental processes of their nutrition.

Whatever further research into the function of fertilizers may reveal, it is not likely seriously to disturb our empirical knowledge of their value.

11. THE NITROGEN CONTENT OF THE SOIL IS MOST CHEAPLY MAINTAINED BY KEEPING UP THE SUPPLY OF HUMUS AND ESPECIALLY BY GROWING LEGUMES, WHICH ALONE OF CROP PLANTS CAN UTILIZE ATMOSPHERIC NITROGEN.

The discovery by Hellriegel, in 1887, of the method by which legumes are able to fix atmospheric nitrogen is with little doubt the most important agronomic advancement made in the past forty years. It was previously known, however, that legumes could obtain more nitrogen than was present in the soil. The value of legumes for green manure or for rotations was known to the ancient Romans and their general use in India and China indicates that it was practiced in these countries in ancient times. In modern agriculture the effect of Hellriegel's discovery has been to emphasize the importance of legumes in cropping systems and thus to increase their use.

Agronomic data in regard to the relative fertilizing value of legumes in which there is a choice, such as the cowpea and the soybean; red clover, alfalfa and melilot; crimson clover and vetch; are far from satisfactory. Thus far the only method of measuring their values in this regard has been the effect on the subsequent crop. No method has yet been devised to determine the actual quantity of atmospheric nitrogen that different legumes may be able to fix under comparable field conditions. There is, however, general belief that the best legume to grow for such purpose is the one which will produce the cheapest unit of yield in dry matter.

Perhaps the most fascinating problem in regard to root nodules is their peculiar systematic distribution. They occur on the roots of five widely distinct families of plants, in each case being caused by apparently the same organism. Theoretically there seems no good reason why they should not become adapted to grow on the roots of all plants.

It is doubtful in my mind if any statement of the humus and nitrogen factor in crop production can properly be included as a *principle*. If the nitrogen factor be admitted, there is no good reason to exclude statements referring to phosphorus, potash, and lime. Perhaps a single broad statement enumerating the essential elements of plant nutrition could more properly be called a fundamental principle.

12. Productivity is approximately maintained by feeding crops to animals and returning the manure to the soil.

This generalization is based mainly on experience, biased perhaps by the most commonly accepted theory of fertility. While there can scarcely be question as to the value of the generalization above stated, it might be difficult to prove its correctness by a sufficient body of critical quantitative data.

13. Selecting the best plants tends to improve the breed.

This statement is apparently broad enough to cover all phases of breeding. It is probably true that primitive man did not cultivate for food any plant that did not already possess high food value as a wild plant. It took no great amount of intelligence to take advantage of variations and to save the best of such for seed. In proof of this may be cited the high degree to which such plants as corn, beans, potatoes, and pumpkins were developed by the American Indians and the grain sorghums by the African negroes.

In modern times, plant breeding received its greatest impetus from Kolreuter's discovery of the method of hybridization. Mendel's discovery of the laws of segregation of hybrids has greatly stimulated the scientific study of these phenomena but can scarcely be said to have had any great influence on practical breeding.

The most important problem associated with breeding is probably that of the nature and origin of mutations.

14. HYBRIDIZATION TENDS TO STIMULATE VIGOR.

The discovery of hybridization by Kolreuter (1760–1770) is undoubtly one of the greatest things that has contributed to the advancement of modern agriculture. That hybrids and crosses often have greater vigor than either parent has long been recognized but, excepting in vegetatively propagated plants, it has not been practicable to utilize this fact. In recent years it has become recognized that this surplus vigor is confined to heterozygote individuals. In some crops, however, nearly every individual is a heterozygote (e. g. corn, timothy, red clover). Shull has brilliantly shown that the occasional dwarfs found in corn fields are homozygote individuals and that the size and vigor of ordinary corn plants is an expression of heterozygosis.

The utilization of the vigor of crosses and hybrids is mainly limited to plants that can be vegetatively propagated. In crosses, however, this advantage is obtained in crops that are normally cross pollinated, like corn and clover. In self-pollinated plants the increased vigor of a cross or of a hybrid is soon dissipated in the Mendelian segregation which occurs.

15. PLANTS INTRODUCED FROM THEIR ORIGINAL TO A NEW AND SIMILAR ENVIRONMENT OFTEN TEND TO BECOME AGGRESSIVE.

The classic examples of this principle are weeds. Most of our American weeds are of Old World origin. In Australia, India and South Africa, cacti from America have spread with great rapidity. In southern Asia and the Malayan Islands nearly all of the aggressive weeds have come from the American tropics.

From an agricultural standpoint this principle is important mainly with broadcasted perennial plants which must hold the ground in competition with other species. For example, every important grass and legume cultivated in America is of Old World origin. These include timothy, bluegrass, redtop, orchard grass, Johnson grass, bermuda, the clovers, alfalfa, cowpeas, velvet beans,—indeed our whole list of cultivated grasses and legumes, with the exception of slender wheat grass, paspalum, carpet grass and beggarweed. This is not because native American grasses and legumes have not been tested but because they have actually been found wanting in ability to hold the ground in competition with the European species.

Only theoretical explanations of aggressiveness have been advanced, such as that the plant is introduced but not its enemies and competitors, the increased vigor being as it were an expression of the rebound from these restraining factors.

Whatever the explanation, the principle involved is scarcely open to doubt.

16. Thinning buds by pruning or otherwise tends to increase the size of the remaining resultant flowers and fruits.

Here the object is secure better quality, especially in size. The total yield in the case of fruits is probably reduced but quantitative data seem to be lacking.

17. Vegetative vigor and reproductive vigor are mutually antagonistic.

Repressing vegetative vigor by the severe pruning, girdling, etc., of woody plants often increases fruitfulness. With annuals as well as perennials the same end may be gained by partial starvation.

Preventing flowering or fruiting when the crop desired is of leaves or roots tends to increase the yield.

18. Dwarfing of perennial plants may be secured by budding or grafting on stocks not wholly congenial.

This principle is employed so that a greater number of plants can be grown on a given area. Theoretically it is perhaps indistinguishable from the preceding principle.

CONCLUSION

The 18 generalizations discussed seem to me the most important that can at present be formulated from our knowledge of the factors of crop production. It may be that some are included that should be omitted or better united with others into broader generalizations. On the other hand, the number might be greatly increased by making the generalizations less broad. It may be questioned whether there is anything to be gained by attempting to formulate definite principles. An evident advantage should be that, in the future, writers will perhaps specify what they mean by the principles or the fundamental problems of agriculture. Investigators have been from time to time urged to attack the more fundamental problems of agriculture,—but there has been a lack of definiteness in pointing out just where these problems lay. If the generalizations that have been enumerated are of this fundamental type, it may be pointed out that only one is clearly the product of the past 50 years, namely, that relating to the nodule bacteria. Most of the others are based on the results secured empirically by long generations of farmers, supplemented in recent times by more accurate experiment. There is still need of more abundant and more accurate data before all these generalizations enumerated can be considered firmly established and a vast amount of work must needs be done before these generalizations can be made more definite and more specific.

While there is necessity for generalizations in agriculture as in every other branch of knowledge, there is also an element of danger in taking them too seriously. In more than one case they have resulted in encouraging error both in teaching and in practice. After all, every plant species with its numerous adaptations is pretty much a law unto itself and it will not do to generalize from the behavior of one or of a few different crop plants. That policy at one time resulted in numerous erroneous generalizations on the part of plant physiologists and the same thing is now occurring in texts dealing with crop plants. In a recent work an experiment is outlined with corn to show that roots must have free air, plants being grown in a pot of ordinary moist soil and in one of water-logged soil. The failure of the corn plants to grow in the latter would perhaps justify the conclusion that corn roots must have air but not the conclusion actually drawn, namely, that roots of all plants must have free air. Under the condition of the experiment, rice or any other plant adapted to growing in water-logged soils would thrive as well if not better in the pot where the corn refused to grow.

Let us consider for a moment the matter of crop production in its botanical relations. The plant as a living structure interests us primarily from three different viewpoints.

1. *Its physiological processes or functions.*
2. *Its hereditary traits or characters.*
3. *Its environmental reaction or adaptation.*

Without in any way minimizing the value of knowledge concerning the physiology of plants, it is clear that in growing crops we are endeavoring both to adapt the plant to the environment at hand and to modify as far as practicable the environment so as to meet most clearly the adaptations of the plant.

From an agronomic standpoint we are concerned primarily with those factors that make for quantity and quality of yield in useful plants.

In agriculture we have long studied the relative yielding capacities of different varieties, and the study and breeding of varieties has received great impetus following the Mendelian discoveries.

So far as the definite reactions of any crop plants to each environmental factor are concerned, there is very little precise information. As long as our methods of investigations are confined largely to complexes of factors our accurate knowledge will continue to be limited and our generalizations hazy and occasionally erroneous. It may here be noted that nearly all of the generalizations that have been discussed are in reality conclusions drawn from observations of the mass effects of environmental factors.

The differing adaptations of plants are such as make it nearly impossible to draw any but very broad generalizations that will apply to all or to many. So much is this the case that it is my deliberate judgment that the best hope of progress in agronomy lies not in the search for broad generalizations, but in a much more intensive study of the environmental relations of every important plant cultivated.

THE ORIGIN OF THE "NITRE SPOTS" IN CERTAIN WESTERN SOILS.[1]

ROBERT STEWART AND WILLIAM PETERSON.

(*A Contribution from the Chemical Laboratory, Utah Experiment Station.*)

It has been observed by a number of investigators that certain soils in the arid west are extremely rich in nitrates. Since nitrogen is undoubtedly the limiting element of plant food in many of our soils this observation is of great importance to western agriculture. Prior to the time this observation was forcibly called to our attention, we had been carrying on extensive investigations regarding the influence of irrigation water upon the production and movement of nitrates in a typical irrigated soil which was extremely rich in all the elements of plant food, except nitrogen. The conditions for bacterial activity,

[1] Presented before the American Society of Agronomy, November 9, 1914.

such as moisture, temperature and reaction were extremely favorable. The application of moisture could be artificially regulated, while the soil was a uniform rich loam with a coarse sand layer at the depth of eight feet. The drainage was well provided for, thus insuring a warm, moist, rich soil, which was also well provided with limestone. The conditions, therefore, were as nearly ideal as it is possible to secure under field condition for the bacterial fixation of free nitrogen of the atmosphere. Yet in our work, extending over a period of eight years in which some thirty thousand determinations of nitric nitrogen had been made, we could not by the wildest stretch of the imagination ascribe a greater quantity of nitric nitrogen than 300 pounds per year as being produced by bacterial action. Of course the amount of nitric nitrogen produced was influenced materially by the nature of the season and the crop produced, as may be observed from table 1.

TABLE 1.[2]—*Total Nitric Nitrogen as Pounds per Acre to a Depth of Ten Feet.*

Season.	Alfalfa.	Potatoes.	Oats.	Corn.	Fallow.
1908	80.1	86.7	68.5	161.1	174.6
1909	24.6	84.2	23.9	81.5	110.6
1910	45.8	99.2	55.4	60.6	133.5
1911	37.9	87.3	24.6	59.2	108.7

The claim, therefore, that many tons of nitrates were produced in certain irrigated soils by bacterial activity under the influence of irrigation water was received with considerable surprise and led us to consider carefully this claim and also the character of the soils in which these accumulations occurred, in order to connect, if possible, their production with the soil conditions under which we were working. It seemed remarkable to us that in our very favorable soils there were no such accumulations of nitrates, if the accumulations noted really were the immediate results of bacterial activity.

A careful study of all published data showed clearly that the soils in which these nitrate accumulations occurred differed in one marked essential from the soils in which our work was carried on. The nitrate accumulations always occurred in soils which were heavily impregnated with alkali, as shown by the high water-soluble salt content. It seemed evident, therefore, that the nitrate accumulations must be associated with the alkali in some way. Since the alkali in the affected area is derived, according to our observations, from the leaching of the country rock, it appeared to us that the nitrates were derived in exactly the same way.

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[2] Stewart and Greaves, Centralblatt fur Bakteriologie, Zweite Abt. Bd. 34, S. 142.

Fortunately this conception was susceptible of definite proof. From the published data it appeared that the nitrates in a given "nitre spot" increased or decreased as the total salts increased or decreased.[3]

This could be clearly shown by comparing the total amount of nitric nitrogen present in the "nitre spot" with the total amount of any other element, for example sulphur, calcium, magnesium or chlorine. For this purpose we selected chlorine as the element which would be most unlikely to be affected by external conditions, such as solubility, etc. It would also be impossible to attribute the increase of chlorine to any other factor than concentration by evaporation of the soil moisture. A careful study of the data showed clearly that there was a definite ratio between the chlorine and nitric nitrogen. This fact is indicated in table 2 which is a typical case of a "nitre spot."

TABLE 2.—*Showing Quantity of Chlorine and Nitric Nitrogen in a "Nitre Spot" as Pounds Per Acre and the Ratio between Them.*

Date.	Total Salts.	Chlorine.	Nitric Nitrogen.	Ratio N : Cl.
Feb. 1908......	36,133	8,368	3,151	1:2.7
Sept. 1909.....	86,400	13,660	5,138	1:2.7

This appeared to us conclusive evidence that the nitrates in the "nitre spots" were clearly the result of concentration by evaporation of the soil moisture. We were, therefore, led to suspect that the "nitre spots" were the direct results of concentration of the water-soluble salts, including the nitrate from (1) the fact that our rich irrigated soil on the Greenville Experimental Farm, on which nitrate experimental work had been carried on for a number of years, were not susceptible to nitrate accumulation, and (2) the fact that in any given "nitre spot" there was a definite ratio between the chlorine and nitric nitrogen which caused both these elements to increase or decrease at the same time, thus indicating that the same influences were at work on both.

A careful study of a number of "nitre spots" in the field confirmed the observation that they were also always rich in other water-soluble salts. This is clearly brought out in table 3, in which the comparison of three such spots in widely separated areas[4] in Utah is given.

[3] Headden, W. P., Colorado Experiment Station Bulletin, 155.

[4] Stewart, Robert, Centralblatt fur Bakteriologie, Zweite Abt., Bd. 36, S. 481.

TABLE 3.—*Percent of Water-soluble Salts in the Soils of Three "Nitre Spots" in Widely-separated Localities in Utah.*

Location.	Total Salts.	Calcium Sulphate.	Sodium Chloride.	Sodium Sulphate.	Nitric Nitrogen P.p.m.
Green River...	12.23	1.82	2.03	5.99	2,000.00
Uintah Basin..	89.78	3.20	1.31	83.17	3,360.00
St. George....	6.59	3.09	2.89		1,298.00

The location and physical characteristics of these and other "nitre spots" led us to the inevitable conclusion that they were the direct result of leaching and concentration of the ground water. And it appeared to us that the nitrates were obtained from the country rock itself and were not the result of immediate bacterial fixation of nitrogen.

A preliminary examination of the shale and the interstratified salt layers in the shale tended to confirm this suspicion, as may be observed in table 4.

TABLE 4.—*Percentage Composition of Shale.*

Material.	Total Salts.	Calcium Sulphate.	Sodium Chloride.	Sodium Sulphate.	Nitric Nitrogen P.p.m.
Shale	1.05	0.12	0.04	0.56	354.0
Salts in shale..	5.19	3.57	0.06	1.55	140.0
Sandstone	1.59	0.61	0.31	0.56	30.0

It appeared, therefore, that the nitrates found in the "nitre spots" were derived from the original rock out of which the soil was formed. This conception was subjected to the rigorous test of collecting and analyzing a large number of samples of the country rock from widely separated areas, the details of which have been published elsewhere.[5] These results showed a wide variation in the nitrate content of the country rock, depending not only on its geological origin but also its location in the geological series. Table 5 contains some of the typical results.

TABLE 5.—*Nitric Nitrogen in Cretaceous Sandstone.*

Location.	Description.	Nitric Nitrogen P.p.m.
Thompson, Utah.	Red Gritty Sandstone................	516.0
Grand Junction, Colo.	Top of Mancos Shale	488.0
Vernal, Utah.	Above Mancos Shale	66.5
Superior, Wyo.	Red Colored Sandstone..............	18.7
Average of twelve Determinations of Sandstone		92.3

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[5] Stewart and Peterson, Utah Experiment Station Bulletin, No. 134.

The cretaceous sandstone, wherever found, always contained appreciable but varying quantities of nitric nitrogen. In table 6 some of the results of the analysis of cretaceous shale are given.

TABLE 6.—*Nitric Nitrogen in Cretaceous Shale*

Location.	Description.	Nitric Nitrogen P.p.m.
Grand Junction, Colo.	Disintegrated Shale, Clay hill.......	1700.0
Vernal, Utah.	Shale	1371.0
Thompson, Utah.	Disintegrated Shale	524.0
Emery, Utah.	Shale	299.5
	Average of 59 determinations	173.0

It is thus readily seen that in the shale itself in many places there is a higher nitrate content than is present in many of the observed "nitre spots" in cultivated soils. In no case in the observed area did we find the shale free from the nitrate. A simple calculation based upon this average nitrate content and the amount of exposed shale in the area studied from Grand Junction, Colorado, to Emery, Utah, shows that there are about 90,000,000 tons of sodium nitrate present in the shale in a widely disseminated form which may readily become concentrated under the influence of ground water or irrigation water so as to produce the characteristic "nitre spots."

It must be emphasized that these "nitre spots" were observed in the uncultivated areas as well as the cultivated soil wherever the water conditions were favorable to their formation. Such conditions in the virgin state were observed at Grand Junction, Colo., Vernal, Price and Emery, Utah, and Lyman, Wyo. At Emery, Utah, in particular, a pronounced case was observed on the side of one of the characteristic barren clay hills. A small irrigating ditch had just been constructed around the hill. Below the ditch on the side of the hill was a slimy, brownish bog possessing all the characteristics of the "nitre spots" observed in the cultivated soils. An analysis of the alkali incrustation of this spot together with an analysis of the shale, clay and ash immediately above the ditch is recorded in table 7.

TABLE 7.—*Nitric Nitrogen in the Alkali of a "Nitre Spot" and in Surrounding Materials.*

Material.	Nitric Nitrogen, Parts per Million.
Shale	79.4
Clay	65.5
Brown Alkali	5590.0
Ash	5448.0

It is thus clearly evident that the "nitre spots" are not characteristic of irrigated cultivated soils alone but are also produced in uncultivated areas whenever the ground water conditions are favorable for their formation.

The nitrate accumulations likewise are not characteristic of the cretaceous geological period alone, but are also found to even greater extent in the original rock of the tertiary and to an appreciable extent even in the jurassic and triassic periods and, so far as we know, possibly in other periods, but the limits of this paper will not permit of a more extended discussion of this phase of the problem.

The "nitre spots" are always characterized by the presence of a brown color which some investigators have attributed to a pigment produced by the azotobacter. Thus Sackett,[6] who firmly believes that the color is the result of such a pigment, says "The two limiting factors in the pigment production are sodium nitrate and mannite." That is, in the absence of sodium nitrate there was no production of color notwithstanding the fact that the nitrate is not produced by the azotobacter and neither is it essential to the development of this organism. Likewise in the absence of organic matter the color was not produced.

Our investigations, however, have given us a simple logical explanation of the production of the color in the "nitre spots," and the reason why the "two limiting factors in the pigment production are sodium nitrate and mannite."

The brown color of the "nitre spots" is produced by the solvent and decomposing action of the sodium nitrate upon the organic matter of the soil in just the same way that the black color of the black alkali spots is produced by the solvent and decomposing action of the sodium carbonate upon the soil organic matter.

This conception was subjected to a rigorous laboratory test. Ten grams of a rich greenhouse soil were treated with 500 cc. of 1 percent solution of the several alkali salts for 24 hours, as in the official humus determination. The relative amount of organic matter dissolved was determined colorimetrically by comparison with the amount dissolved by 500 cc. of distilled water in a similar manner. The actual amount of organic matter dissolved by the water was determined by evaporating an aliquot portion of the extract to dryness, weighing, igniting and again weighing. Water dissolved 0.57 per cent of organic matter.

The relative amount of organic matter dissolved is recorded in table 8. It will be noted by a careful study of these data that all the salts of sodium and potassium, with the single exception of potassium chloride, have a solvent action on the organic matter of the soil. The

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[6] Sackett, W. G., Colorado Experiment Station Bulletin, 179, p. 37.

TABLE 8.—*Organic Matter Dissolved by a One Percent Solution of Various Alkali Salts.*

Bases.	Sodium.				Potassium.				Magnesium.			Calcium.	
Salts	CO_3	SO_4	Cl	NO_3	CO_3	SO_4	Cl	NO_3	SO_4	Cl	NO_3	Cl	NO_3
Percent dissolved......	5.7	1.19	0.72	0.8	4.21	0.78	0.57	1.4	0.57	0.48	0.49	0.19	0.20

salts of calcium and magnesium, however, with the exception of magnesium sulphate, which is neutral, have a repressive action on the solubility of the organic matter. These salts dissolve far less organic matter than does the distilled water itself. A complete explanation of the phenomona noted may be obtained by a consideration of the law of mass action. It will be recalled that in the old official humus determination it is necessary to leach the soil with 1 percent hydrochloric acid before extraction with 4 percent ammonia, since the calcium and magnesium salts of the organic acids are insoluble in the ammonia. In a consideration of the above data with respect to calcium and magnesium salts, therefore, it must be remembered that the active mass has been materially increased with the resulting conversion of the soluble organic matter into insoluble organic salts, as illustrated below by means of sodium oxalate.

$$CaCl_2 + (COO)_2Na_2 = \underset{\text{Insoluble}}{(COO)_2Ca} + 2NaCl,$$

while with the addition of sodium or potassium salts the active mass is increased on the other side of the equation, thus forcing the reaction in the opposite direction. Thus:

$$(COO)_2Ca + Na_2CO_3 = \underset{\text{Insoluble}}{CaCO_3} + (COO)_2Na_2.$$

The carbonates of sodium and potassium have a greater solubility for organic matter than the chlorides, sulphates or nitrates because the acid radical unites with calcium or magnesium, forming the insoluble calcium or magnesium carbonates, thus removing the calcium or magnesium from the sphere of action, and at the same time converts the organic acid into a sodium salt which is soluble.

The calcium or magnesium carbonate produced forms a powder which cements the soil particles together, thus giving to the soil a hard compact character, which is characteristic of the black alkali spots.

The color is produced by the sodium carbonate, because, being a salt of a weak acid and a strong base, it readily hydrolyzes, producing sodium hydroxide, or caustic soda, which, as is well known, acts on carbohydrates, producing a brown color, the intensity of which depends on the concentration of the sodium or potassium hydroxide, thus readily accounting for the production of the color of black alkali spots. Likewise, in the case of sodium or potassium nitrate, the salt being the result of this union of a strong base and a stronger acid than carbonic acid, does not hydrolyze so easily and as a result there is a smaller amount of sodium or potassium hydroxide present and necessarily the production of a milder color as observed in the brown alkali spots. The sodium and potassium sulphate and chloride, being the salts of strong acids and bases, do not hydrolyze, therefore caustic alkali is not produced, and consequently the color is not produced by these alkali salts. Likewise the calcium and magesium salts give no opportunity for the production of the caustic alkali so do not produce the color.

It is thus clearly seen that the color in the " nitre spots " is the result of the solvent and decomposing action of sodium or potassium nitrate upon the organic matter of the soil. It should, in this connection, be clearly kept in mind that the original rock of the afflicted area, both the sandstone and shale, is coal- and oil-bearing material, some of the most important coal mines of the intermountain area being located in this district.

Our investigations thus clearly demonstrate that (1) the nitrates of the " nitre spots " are derived by concentration from the original rocks contributing to the soil formation, and (2) that the color of these spots is the direct result of the solvent and decomposing action of the sodium or potassium nitrate upon the organic matter of the soil.

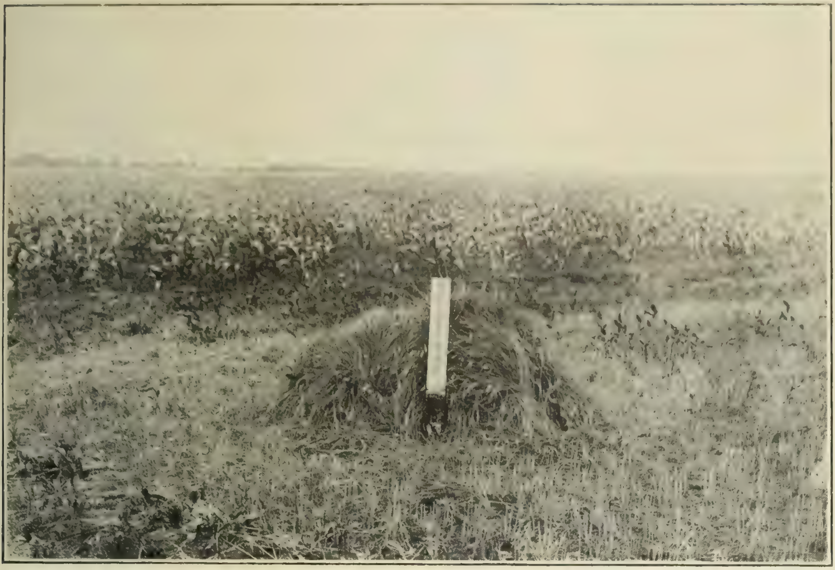

FIG. 1.—The shocked grain on Plat 1, July, 1911. Seedbed prepared by disking the ground the day the wheat was sown. Yield per acre, 6 bushels of grain and 590 pounds of straw.

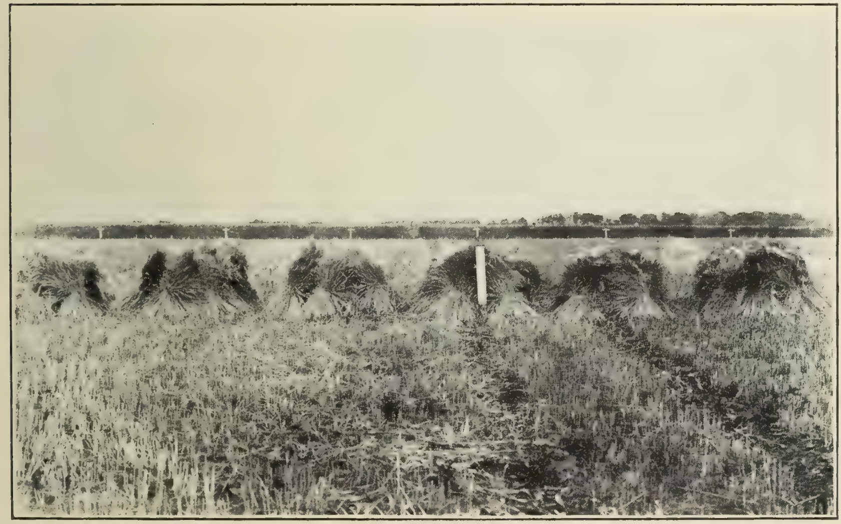

FIG. 2.—The shocked grain on Plat 9, July, 1911. Seedbed prepared by plowing seven inches deep July 15 and working thoroughly. Yield per acre, 40 bushels of grain and 3550 pounds of straw.

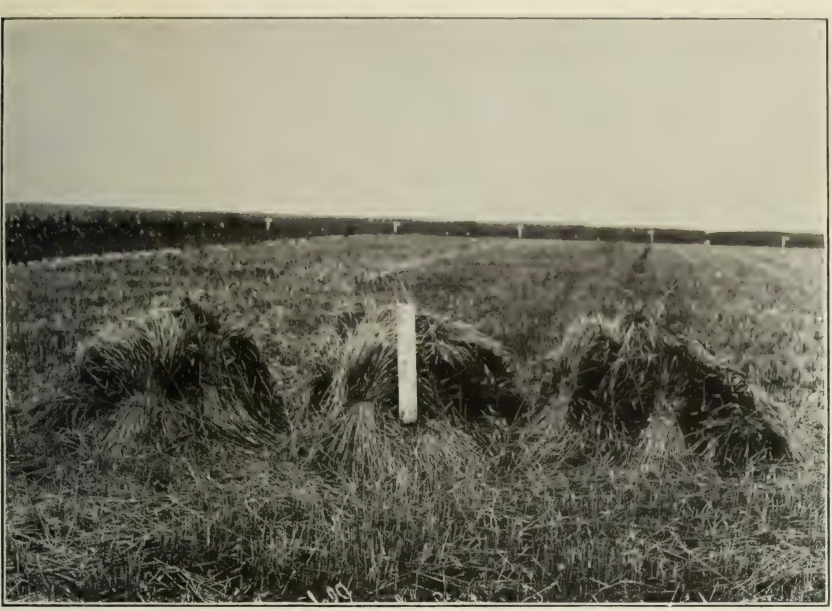

FIG. 1.—The shocked grain on Plat 2, July, 1911. Seedbed prepared by plowing seven inches deep September 15 and working thoroughly. Yield per acre, 17.50 bushels of grain and 1450 pounds of straw.

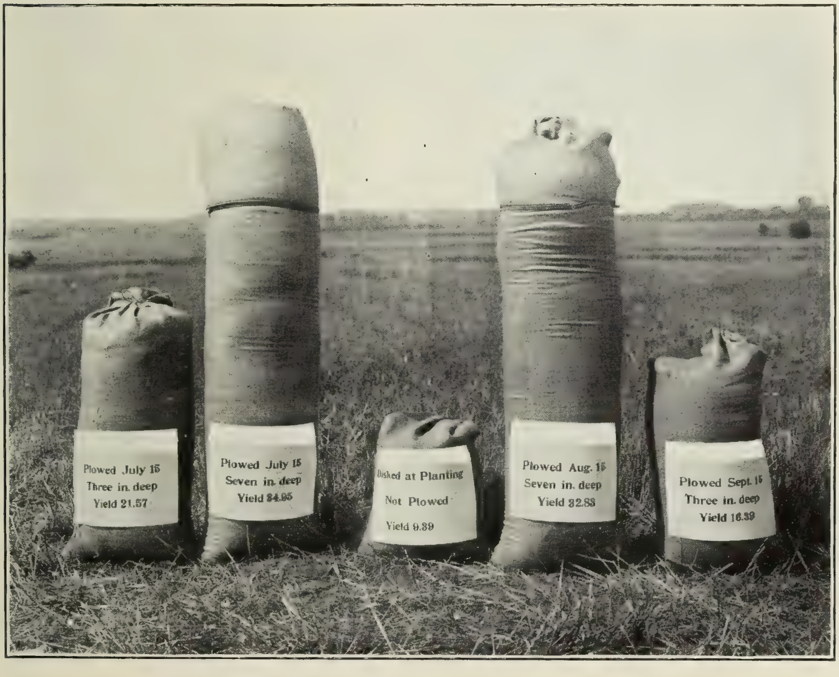

FIG. 2.—The grain produced in 1913 on five tenth-acre plats prepared in different ways for winter wheat. (Yield corrected by check plats.)

THE EFFECT OF DIFFERENT METHODS OF PREPARING A SEED BED FOR WINTER WHEAT UPON YIELD, SOIL MOISTURE, AND NITRATES.

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(*Read before the American Society of Agronomy, November 9, 1914.*)

(Plates V and VI; text figures 24 and 25.)

The investigational work which it is wished to present at this time was undertaken for the purpose of studying the influence of different methods of preparing the seed bed for winter wheat upon conservation of moisture, liberation of plant food as indicated by available nitrogen and upon the growth of the crop as determined by the production of grain and straw. Considerable data are available to show that the earlier the seed bed is prepared, the greater the yield secured, but very little information is available to show what factors are responsible for the increased production. In most instances, where an explanation has been offered, the increase in yield has been attributed to the conservation of moisture in the early plowed and thoroughly prepared ground.

In the summer of 1909 fifteen one-tenth acre plats were laid out on the Kansas Agricultural College farm near Manhattan and the work, which has been continued to the present time, was started. For two seasons previous, some preliminary work had been done upon land that proved to be too ununiform for the project. The area of ground finally selected for the work is low upland. This soil is a dark brown silt loam about ten inches deep, the subsoil to a depth of at least six feet being a reddish-brown silty clay loam. The upper portion of the subsoil contains more clay and is quite plastic, but the content of fine and very fine sand increases with depth so that in the fifth and sixth foot the subsoil contains a considerable quantity of the finer grades of sand. As a rule, the soil is retentive of moisture and is not quickly affected by dry weather. The soil over the area shows some variation, the south part being slightly heavier, darker, and more plastic than the ground at the north end of the area. This condition is most noticeable in the subsurface soil.

The difference in texture affects the moisture equivalent and wilting coefficient which, for the average of the surface four feet at the south end of the area, are 25.4 percent and 13.8 percent respectively,

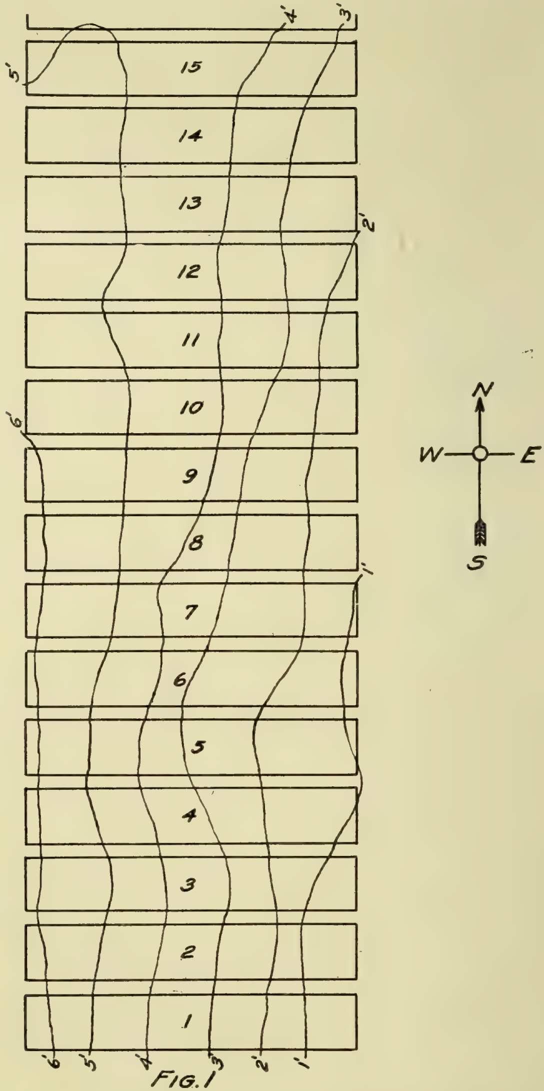

FIG. 1

CONTOUR MAP OF THE WHEAT SEED-BED PREPARATION PLATS

FIG. 24.—A contour map of the wheat tillage plats.

and for the north end of the area are 23.5 percent and 12.8 percent respectively, there being, therefore, a difference of one percent in wilting coefficient in different parts of the area.

The plats slope gently to the south and east, but are comparatively level. The accompanying contour map (Fig. 24) shows the topography of the area and the method of platting.

METHOD OF TREATMENT.

Eleven different methods have been used in preparing the seed bed for wheat. They are as follows:

1. Disking at time of seeding just sufficiently to loosen surface soil.
2. Plowing September 15, seven inches deep, and worked down.
3. Plowing September 15, three inches deep, and worked down.
4. Plowing August 15, seven inches deep, and worked down.
5. Plowing August 15, seven inches deep, but not worked down until September 15.
6. Plowing July 15, seven inches deep and worked down.
7. Plowing July 15, three inches deep and worked down.
8. Double disking July 15, and plowing seven inches deep August 15, and worked down.
9. Double disking July 15, and plowing seven inches deep September 15, and worked down.
10. Listing July 15, and working down the ridges.
11. Listing July 15, and splitting the ridges August 15.

Fifteen plats are required to accomodate the work since five check plats, each receiving the same treatment, are placed in such a way that a check plat occurs as every third plat in the series.

Each plat has been prepared for wheat in the same way each season, so that the effect of any given treatment has become accumulative. All plats with the exception of those purposely left without working for a definite period were worked in the best possible manner. No attempt was made to prepare a seed bed in the cheapest way, but rather it was the aim to prepare as good a seed bed as possible regardless of cost. Thus the plats plowed in July and August were worked as often as necessary to keep down weed growth and to maintain a soil mulch. The plats plowed in September were worked sufficiently to prepare as good a seed bed as possible under the conditions. The quantity of work actually necessary to prepare a good seed bed and to keep the soil in good condition varied from season to season, due to differences in weather conditions. Thus, in 1909 it was possible to prepare a good seed bed on ground plowed seven inches deep in July for $4.00 an acre, while it cost $6.25 to prepare a seed bed equally as good in the summer of 1911. All plats were sown at the same time, with a disk drill, sowing crosswise the plats. Bearded Fife, a high-yielding strain of semi-hard red winter wheat was sown at the rate of one and one-fourth bushels per acre.

The Yield of Grain and Straw.

The wheat winter-killed in the winter of 1909 so that a crop was not secured in 1910. The yields of grain and straw obtained from each method of preparation for the seasons of 1911, 1912, 1913 and 1914, and the average for the four years, are shown in Table 1.

Table 1.—*Yield of Wheat from Each of the Different Methods of Preparation for the Seasons of 1911, 1912, 1913, and 1914.*

Plat.	Treatment.	Yield per Acre.									
		1911.		1912.		1913.		1914.		Average.	
		Grain, Bu.	Straw, Lbs.	Grain, Bu.	Straw, Lbs.	Grain, Bu.	Straw, Lbs.	Grain, Bu.	Straw, Lbs.	Grain, Bu.	Straw, Lbs.
1	Double disked, not plowed	6.00	590	4.17	410	13.00	1,205	21.83	2,710	11.25	931
2[1]	Plowed Sept. 15, 3″ deep.	17.50	1,450	6.83	950	20.00	1,840	23.33	3,615	16.91	1,963
3	Double disked July 15, plowed Sept. 15, 3″ deep.	25.00	2,120	6.33	880	29.91	3,105	25.83	3,830	21.76	2,481
4	Double disked July 15, plowed Aug. 15, 3″ deep.	34.83	3,010	6.33	1,120	31.00	3,480	26.00	3,320	24.54	2,744
5[1]	Plowed Sept. 15, 3″ deep.	14.50	1,130	7.83	900	16.33	1,560	21.67	2,820	15.08	1,603
6	Single listed July 15.	37.66	3,140	5.33	895	28.58	2,945	23.42	2,905	23.00	2,396
7	Listed July 15, ridges split Aug. 15.	37.16	3,070	5.75	1,055	31.00	3,410	27.17	3,000	25.29	2,634
8[1]	Plowed Sept. 15, 3″ deep.	18.83	1,470	10.58	1,035	18.83	1,470	27.92	3,225	19.04	1,800
9	Plowed July 15, 7″ deep.	40.00	3,550	9.75	1,250	36.00	4,170	25.83	3,070	27.87	2,760
10	Plowed Aug. 15, 7″ deep.	28.00	2,320	14.33	1,540	32.50	3,250	25.58	2,415	25.10	2,506
11[1]	Plowed Sept. 15, 3″ deep.	14.66	1,170	10.66	895	14.66	1,230	24.92	3,185	16.23	1,619
12	Plowed Aug. 15, not worked until Sept. 15.	21.66	1,800	10.08	1,185	20.47	2,870	26.08	3,455	19.58	2,328
13[2]	Plowed Sept. 15, 7″ deep.	10.66	940	9.42	845	14.17	1,130	23.17	3,520	14.36	1,609
14[1]	Plowed Sept. 15, 3″ deep.	12.16	1,020	8.42	805	12.50	1,090	21.70	2,868	13.69	1,446
15	Plowed July 15, 3″ deep.	29.83	2,360	5.83	880	17.33	2,040	20.88	2,377	18.46	1,914

[1] Plowed 7″ deep 1910 and 1911.

[2] Plowed 3″ deep 1910 and 1911.

The largest yield, 27.87 bushels of grain and 2,760 pounds of straw, was obtained from the ground plowed seven inches deep in July. Ground plowed on the same date but only three inches deep produced an average yield of but 18.46 bushels of wheat and 1,914 pounds of straw per acre, a difference in yield of grain of 9.41 bushels. A part of this difference in yield is accounted for by the variation in soil as indicated by the check plats. The ground that was plowed shallow was on the poorer soil.

Ground plowed seven inches deep in August produced an average of 25.10 bushels of grain and 2,306 pounds of straw. Ground plowed on the same date and at the same depth, but left without working for one month, produced but 19.58 bushels of grain and 2,328 pounds of straw. Another plat (No. 13), plowed one month later, but otherwise worked at the same time and given the same amount of work as plat 12, produced but 14.36 bushels of grain and 1,609 pounds of straw. These results demonstrate the value of working ground plowed early; but they also show the importance of early plowing even though it is impossible to work the ground as quickly as it should be worked after the plowing is done.

Ground plowed shallow (three inches deep) in September varied in yield from 13.69 bushels to 19.04 bushels per acre on the five different check plats, the average being 16.19 bushels of grain and 1,686 pounds of straw per acre. This is 8.91 bushels less wheat than was produced on August-plowed ground and 11.68 bushels less wheat than was produced on July-plowed ground.

Ground that has been single listed each season in July produced an average yield of 23.00 bushels of grain and 2,396 pounds of straw, while ground that has been double listed, listed in July and the ridges split in August, produced an average yield of 25.29 bushels of grain and 2,634 pounds of straw. Neither method has produced as much wheat or straw as deep plowing done at the same time as the listing. In fact, ground plowed in August has exceeded in yield, ground single listed in July.

Double disking in July ground that was to be plowed in September has greatly increased the yield over undisked ground plowed the same day. Plat 3, double disked each season in July and plowed in September, produced an average yield of 21.76 bushels of grain and 2,481 pounds of straw, while the adjoining check plat plowed the same depth, the same day, but not double disked, produced but 16.91 bushels of grain and 1,963 pounds of straw. This is a difference of 4.85 bushels of grain and 518 pounds of straw per acre in favor of the ground double disked two months before plowing. Ground double disked in July and plowed in August produced slightly less wheat as an average of the four years than ground plowed the same date but not previously disked. The disked ground, however, produced slightly more straw.

The lowest yield was obtained from ground that was not plowed but disked each season at the time of planting just sufficiently to secure enough loose dirt to cover the seed. This plat has produced

11.25 bushels of grain and 931 pounds of straw per acre as an average of the four years. This yield is nearly one-third less than that secured from ground plowed three inches deep in September and but forty percent of that secured from ground plowed seven inches deep in July.

Ground worked early, regardless of the method of working, has usually produced a comparatively high yield; while ground worked late, regardless of the method, has usually resulted in a low yield.

Moisture and Nitrates.

Moisture and nitrate samples were taken each season at the time of seeding the wheat in the fall, at the time spring growth started, and at the time of harvesting the crop. In addition, samples were usually taken at intervals of one month during the time the ground was being prepared. Moisture samples were taken regularly to a depth of four feet and nitrate samples at a depth of three feet, except at the time of seeding in the fall and at harvest in the spring, when the moisture samples were taken in most seasons to six feet in depth. A one-inch steel tube was used to take the samples. Duplicate samples were taken for both moisture and nitrate determinations. They were taken in sections of one foot and determinations of each foot made separately. The moisture was determined by drying the sample in an air-bath oven at 105° C. The nitrates were determined by the phenol-di-sulphonic acid method.

In the five seasons over which this work extended, each season has presented slightly different results, because of varying weather conditions. An average of the moisture and nitrate data for the five seasons would not, therefore, present as clear a study as the results of a single normal season. Since space will not permit a presentation of each season's results in detail, the discussion will be confined to the results secured from the last normal wheat crop. The summer of 1913 was so dry that ground could not be properly prepared for wheat. Ground plowed in July and August remained unworked until the middle of September because no rain fell during this period. The results of the moisture and nitrate work with the wheat crop of 1913, therefore, will be used instead of those from the crop of 1914.

The fall of 1912 and the summer of 1913 were abnormally dry, yet the season on the whole was a favorable one for winter wheat. Table 2 gives the precipitation for the crop season of 1912–1913.

During the months of July, August and September, there was sufficient moisture to keep the surface soil moist and in good condition

TABLE 2.—*Precipitation at Manhattan, Kansas, from July, 1912 to June, 1913, Inclusive.*

	1912.						1913.						
Day.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
1	....	....	....	....	....	.35	....	....	....	....	....	....	....
2	.25	.15	T	.02	....	.05	....	.19	....	.45	....	....	....
3	.16	....	.74	....	....	....	....	....	....	....	.75	....	....
4	....	....	....	....	....	....	....	....	....	....	.13	....	....
5	.15	.21	....	....	T	T	....	....	....	....	.07	.78	....
6	....	.62	....	....	....	....	.08	....	....	.35	....	....	....
7	....	....	....	....	....	....	.20	....	....	1.57	....	.11	....
8	....	.27	....	.60	....	....	.02	....	....	....	....	....	....
9	....	.20	....	....	....	....	....	....	....	.12	....	....	....
10	T	....	....	.75	....	....	....	....	....	.01	2.00	....	....
11	....	....	T	1.35	....	T	....	....	....	....	.65	....	....
12	1.85	....	T	....	.05	....	....	....	....	....	....	....	....
13	....	....	.42	....	....	....	....	....	....	....	.14	....	....
14	....	.37	1.78	....	....	....	....	....	.34	....	.30	....	....
15	....	.36	....	....	....	....	....	....	....	....	....	....	....
16	....	....	....	....	....	.01	....	....	....	....	....	....	....
17	....	....	....	....	....	....	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....	....	....	....	....	....	....
19	....	....	....	....	....	....	....	....	.22	....	.91	....	....
20	....	1.20	....	....	....	....	....	....	....	....	.12	....	....
21	.40	....	....	T	....	....	....	.53	....	....	....	.95	....
22	....	....	....	T	....	....	.04	....	....	....	....	....	....
23	....	....	....	....	....	....	....	....	.02	1.00	....	....	....
24	.03	....	.23	....	....	....	....	....	....	.01	....	....	....
25	....	....	....	....	....	....	....	....	....	....	....	....	....
26	....	....	....	....	....	....	....	....	....	....	....	....	....
27	....	....	....	....	....	....	....	.22	....	....	....	....	....
28	.39	T	.33	....	....	....	....	....	....	....	....	....	....
29	....	....	....	....	....	....	....	....	....	....	....	....	....
30	....	....	....	....	....	....	....	....	....	....	....	.52	....
31	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals	3.23	3.40	3.50	2.72	.05	.41	.34	.94	.58	3.51	5.07	2.36	....
	Total for year 1912–1913.												26.11
Average monthly precipitation for 50 yrs.	4.65	3.88	3.10	2.22	1.34	.80	.70	1.13	1.35	2.54	4.54	4.62	....
	Average annual precipitation for 50 years.												30.81

for cultivation so that it was possible to prepare a good seed bed for the crop regardless of the time at which the plowing was done. The rainfall during the winter was comparatively light, but the moisture came principally in the form of rain on unfrozen ground and was, therefore, largely absorbed. The total rainfall between seeding and harvest was but 14.84 inches.

Table 3 gives the total and available moisture in the surface four feet of soil at seeding time and at harvest, the pounds of nitrates in an acre three feet of soil at seeding, and the yield of grain and straw per acre for the season of 1913.

Table 3.—*Moisture in Four Feet of Soil at Seeding and Harvest and Pounds of Nitrates in Three Feet of Soil at Seeding Time, and Yield Per Acre, Season of 1912–1913.*

Plat.	Treatment.	Average Percent of Moisture in 4 Feet.				Total Pounds of Nitrates in 3 Ft. October 9.	Yield per Acre.	
		Seeding.		Harvest.				
		Total.	Available.	Total.	Available.		Grain, Bushels.	Straw, Pounds.
1	Double disked Sept. 27, not plowed	20.57	6.77	18.8	5.00	22.43	13.00	1,205
2	Plowed Sept. 15, 3″ deep	19.56	5.83	15.3	1.57	76.15	20.00	1,840
3	Double disked July 15, plowed Sept. 15, 3″ deep.	20.21	6.55	14.2	.54	263.16	29.91	3,105
4	Double disked July 15, plowed Aug. 15, 3″ deep	20.65	7.06	14.58	1.00	384.70	31.00	3,480
5	Plowed Sept. 15, 3″ deep	19.11	5.60	15.8	2.29	73.66	16.33	1,560
6	Single listed July 15	18.63	5.19	15.72	2.38	372.15	28.58	2,945
7	Listed July 15, ridges split Aug. 15	17.85	4.48	14.76	1.39	522.06	31.00	3,410
8	Plowed Sept. 15, 3″ deep	17.98	4.68	15.49	2.19	77.71	18.83	1,470
9	Plowed July 15, 7″ deep	18.02	4.80	13.90	.68	407.94	36.00	4,170
10	Plowed Aug. 15, 7″ deep	19.71	6.55	15.52	2.36	255.76	32.50	3,250
11	Plowed Sept. 15, 3″ deep	18.26	5.18	15.19	2.11	52.38	14.66	1,230
12	Plowed Aug. 15, 7″ deep, not worked until Sept. 15	19.79	6.78	14.81	1.80	243.20	26.47	2,870
13	Plowed Sept. 15, 7″ deep	19.21	6.27	15.02	2.08	76.83	14.17	1,130
14	Plowed Sept. 15, 3″ deep	17.84	4.97	15.17	2.30	57.30	12.50	1,090
15	Plowed July 15, 3″ deep	18.72	5.92	14.84	2.04	517.07	17.33	2,040

There is very little, if any, correlation between the amount of moisture in the soil at seeding and the yield of wheat secured. Plat No. 1, which was double disked at seeding September 27, but not plowed, contained nearly as much moisture at seeding time as any other plat because the moisture in the subsoil had not been depleted by large crops grown in previous years. Yet, with this relatively large supply of moisture, the plat produced less grain and straw than any other plat in the test. Likewise, all the plats plowed in September contained as large a supply of available moisture as the plats plowed earlier in the season, yet they produced much smaller yields of wheat. Plat No. 9, plowed July 15, seven inches deep, produced the highest yield of wheat, yet this plat was one of the driest plats at seeding because two years before it had produced a large yield and the subsoil had not, in the meantime, been replenished with moisture. It is evident, therefore, that the supply of moisture in the soil at seeding time was not the factor determining yield this season.

A comparison of the moisture left in the ground at harvest with the yield produced, will show that those plats which produced high yields used nearly if not quite all of the available moisture in the soil, while the low-yielding plats left in the soil from 1.5 to 5 percent of available moisture. Apparently, the low yield was not the result of

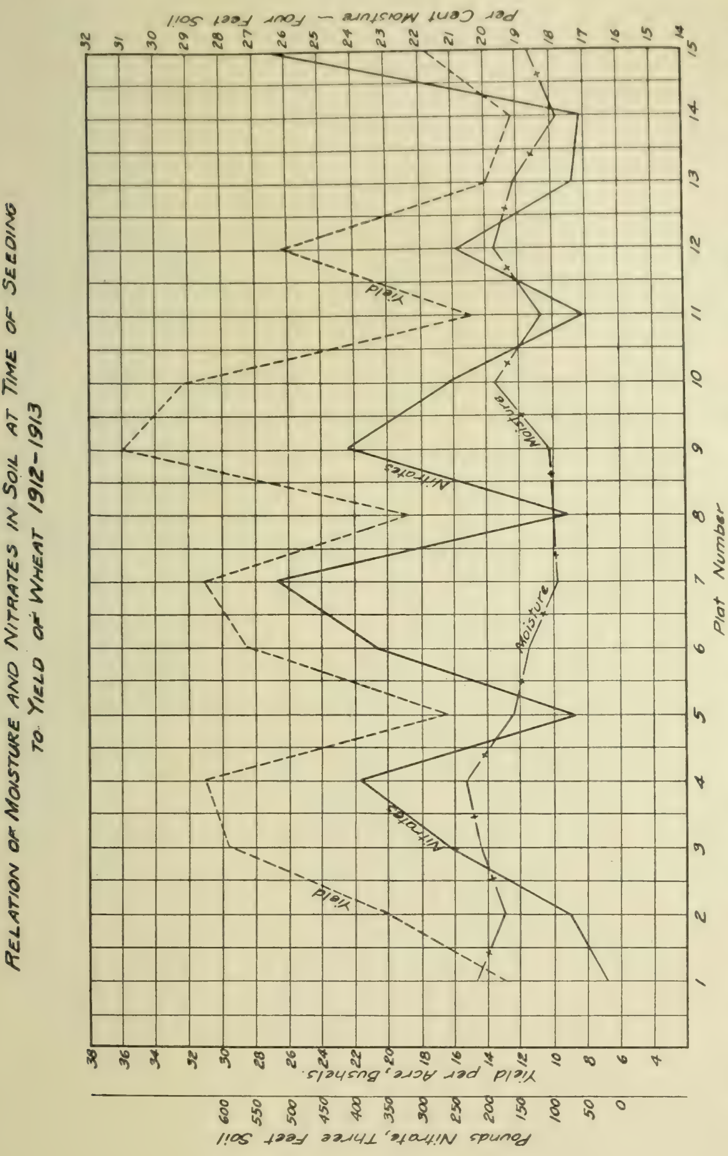

Fig. 25.—Graphs showing the relation of moisture and nitrates in the soil at time of seeding to yield of wheat, 1912–13.

a deficient supply of moisture. Plat No. 1, which produced but 13.00 bushels of wheat per acre, the lowest yield of any plat, had five percent of available moisture still unused at harvest.

When the yield of wheat is compared with the nitrates in the soil at seeding, it will be seen that they are very closely correlated. In every instance where a large quantity of nitrates is found, the yield is high, and in every instance where the nitrates are low, the yield is low. One exception to this is plat No. 15 which was plowed July 15, three inches deep. This plat is located at the north end of the area and was injured to some extent by chinch bugs which moved into the plat from an adjoining field of barley. The yield is not, however, in every instance, in direct proportion to the supply of nitrates in the soil at seeding. When the quantity of nitrates exceeds 250 pounds, the increase in yield is not in proportion to the nitrate content of the soil. Perhaps in these cases, insufficient moisture, an insufficient supply of plant food, or some other element may have prevented a higher yield.

The close relation that exists between the supply of nitrates in the soil and the yield would indicate that the supply of available nitrogen was at least a very important factor and that it was undoubtedly the limiting element of plant food on all the plats not worked until late in the season, while on the early plowed plats, more than enough nitrogen was available to supply the needs of the crop. That this was the case, is well shown from results secured during 1913 on the fertility plats at this station.

Two different fields were fertilized with different combinations of fertilizers. One field which had been cropped continuously to wheat for several years was plowed in July and the seed bed prepared in the best possible manner; the other field had been in corn and a seed bed was prepared for wheat by disking the corn stubble. Nitrate determinations were not made of the soil of either field, but the field plowed in July undoubtedly possessed a high nitrate content. The results secured from fertilizers on this field are shown in table 4.

TABLE 4.—*Effect of Fertilizers upon Yield of Wheat on July-plowed Ground, Season of 1913.*

Treatment.	Yield Grain per Acre Bushel.	Percent Increase Due to Fertilizer.
None	17.64	
Phosphorus and potassium	19.34	9.64
Phosphorus and nitrogen	18.56	5.22
Potassium and nitrogen	15.38	—12.81
Potassium, phosphorus, and nitrogen	16.39	— 7.09

The nitrogen was supplied in the form of nitrate of soda applied at the rate of 160 lbs. to the acre. One-third was applied in the fall and two-thirds the following spring. Nitrate of soda did not increase the yield of wheat on the field plowed in July. The large quantity of nitrates liberated in the preparation of the seed bed supplied to the wheat plants all the nitrogen they needed for growth. It will be observed that there was a slight decrease in yield where the nitrogen fertilizer was combined with potassium both with and without phosphorus. A decreased yield often occurs at this station when a heavy application of nitrate of soda is made in dry seasons to soil already containing a large store of available nitrogen.

On the corn ground where a seed bed was prepared for wheat by double disking the ground after the corn crop was harvested, the nitrates in the soil were undoubtedly much lower. The effect of nitrogen fertilizer on this ground is shown in Table 5, which follows:

TABLE 5.—*Effect of Fertilizers on Yield of Wheat on Disked Corn Ground. Season of 1913.*

Treatment.	Yield Grain per Acre. Bushels.	Percent Increase Due to Fertilizer.
None	11.43	
Phosphorus and Potassium	14.19	24.14
Phosphorus, Potassium and Nitrogen	25.20	120.47

This same quantity of nitrate of soda was used on the plats in this field as was applied to the field where the ground was plowed in July. Under these conditions, where there was not an opportunity to work the ground long before seeding and thus liberate a large quantity of nitrates in the soil, an application of nitrogen in the form of nitrate of soda gave an increase in yield of nearly 100 percent. It appears, therefore, that on late plowed ground or on ground otherwise worked late nitrogen was not liberated in sufficient quantities to supply the crop with the amount necessary for the maximum growth and under such conditions, a lack of nitrogen has been responsible for the low yields of wheat secured. On the other hand, where the ground was prepared early in the season, sufficient nitrogen was liberated to supply the needs of the plant and additional nitrogen in the form of nitrate of soda did not increase the yield.

Early plowing in preparing land for wheat appears to be of value under eastern Kansas conditions rather because of the large supply of plant food liberated, especially nitrates, than for any additional moisture that is stored in the soil by the early cultivation. It also appears that poor results are secured from late plowing chiefly because plant food is not liberated in sufficient quantities to supply the needs of the crop.

AGRONOMIC AFFAIRS.

IN PASSING.

After five years of consecutive service as secretary of the Society and editor of its publications, it became necessary for the writer to decline further honors in that direction. This severing of official connection in no sense indicates a lessening of interest in the American Society of Agronomy or in the progressive development and fruition of the instructional and experimental phases of our science. On the contrary, the routine requirements of the double service mentioned have retarded serious attention to certain agronomic activities long projected. It is now his hope to give time and thought to some of these, including the work of the committee on agronomic terminology.

Under the circumstances it may not be unfitting to review some of the material achievements of the Society during the five-year period. The net membership has increased from 146 to 396, a net gain of 250, or an average net gain of 50 members each year. During this same period pubication has been established, carried through four annual bound volumes of proceedings, then changed in form to a journal, issued quarterly in 1913, and finally brought to the present standard of bimonthly issues, as represented by volume 6 during the current year. By committee activity the Society has fostered and ratified the affiliation of American agricultural organizations, has presented plans for standardizing soil classification and mapping, has made initial recommendations regarding procedure in field experiments and has under consideration needed improvement in varietal nomenclature and agronomic terminology.

Clearly the Society has made some material progress. But material achievements are commendable only as they are the index of a commendable spirit within. Without doubt this commendable spirit exists. The expanding activities of the Society seem to have brought about a feeling of solidarity, a sense of unity of purpose in the membership. Owing to the recent and diverse, and also somewhat illogical, development of agronomy, the workers therein have not had the sense of unity characterizing the workers in some other and older branches of science. Like them, however, the agronomist is seldom a self-seeker. He desires to obtain only that he may give. The writer can speak appreciatively on this point, after these years of professional and personal contact with very many of the agronomists of America. So, too, as a Society, they have sought to accomplish only that they might the better make return to the constituency they serve. Doubtless profound reasons underlie the general altruism of agronomy. Perhaps it is the daily touch with the great and complex, yet fundamentally simple problems involved in the interrelations of crop and climate and soil. Perhaps it is the daily contemplation of the tremendous import to humanity in the successful solution of these problems. The welfare of the individual, of the nation, of the race, is bound up in this never-ceasing search. The thought grips the mind, steels the will and tempers the soul in its high purpose.

NOTES AND NEWS.

S. W. Fletcher, former director of the Virginia Station, is located in Washington, D. C., where he is using the excellent library facilities afforded to complete a monograph covering the history, botany and culture of the strawberry.

E. E. Free, formerly investigating potash deposits for the U. S. Bureau of Soils, and more recently a consulting engineer in San Francisco, is now pursuing some special advanced studies at Johns Hopkins University.

L. H. Goddard, formerly of the Rural Organization Service of the U. S. Department of Agriculture, is now agriculturist in charge of Farm Management Demonstrations, one of the three divisions of the Office of Demonstration Work in the North and West.

O. O. Churchill, agronomist of the Oklahoma College and Station, has resigned to take effect December 31, 1914, to become professor of agronomy at the North Dakota Agricultural College, where the agronomic work of the College and Station has been entirely separated.

J. M. Westgate, agronomist in charge of clover investigations in the office of forage crop investigations, will leave for Hawaii about January 1, 1915, where he becomes agronomist in charge of the Hawaii Experiment Station, at Honolulu.

Hilmer H. Laude, formerly county adviser at Palmyra, Mo., has since last spring been superintendent of the cooperative rice-experiment farm at Beaumont, Texas, maintained cooperatively by the U. S. office of cereal investigations and the Texas experiment station.

C. G. Hopkins has resumed his duties as chief in agronomy and chemistry at the Illinois experiment station after a year's leave of absence as agricultural manager of the Southern Settlement and Development Organization.

W. L. Carlyle, formerly dean of agriculture at Idaho University and director of the experiment station, has been elected director of the Oklahoma Station.

The ten-day period from November 9 to 18, inclusive, was occupied by the sessions of 13 agricultural organizations which gathered in annual meeting at Washington, D. C. The list of societies is as follows:

American Association for the Advancement of Agricultural Teaching.
American Association of Farmers' Institute Workers.
American Farm Management Association.
American Society of Agronomy.
American Society of Animal Production.
American Society of Milling and Baking Technology.
Association of American Agricultural Colleges and Experiment Stations.
Association of Feed-Control Officials of the United States.
Association of Land-Grant Engineers.
Association of Official Agricultural Chemists.
Association of Official Seed Analysts.
National Association of State Universities.
Society for the Promotion of Agricultural Science.

NEW BOOKS.

Wheat. A Practical Discussion of the Raising, Marketing, Handling and Use of the Wheat Crop, Relating Largely to the Great Plains Region of the United States and Canada. By A. M. TEN EYCK, Professor of Soils, Agricultural Extension Department, Iowa State College. Campbell Soil Culture Co., Lincoln, Nebr., 1914. Small 8vo. Pages 194. Figs. 39.

In the words of the author, "this book is not technical but treats the subject in a practical way and is written especially for the study and use of those who are engaged in wheat farming." No one will question that there is a real field for a little book on wheat and wheat culture especially adapted for the grower of the crop. In a general way this book very well meets this need.

The chapter headings are as follows: (1) Introduction, (2) Habits and Types, (3) Seed Improvement, (4) Soil, Climate and Cultivation, (5) Wheat Seeding and Cultivation, (6) Harvest and Yield, (7) Threshing and Marketing, (8) Wheat Enemies, (9) Maintaining Soil Fertility, (10) Wheat on the Pacific Coast, (11) Wheat Growing in Canada, (12) Culture Methods, (13) Rotation of Crops, (14) Seeding Machinery. The appendix contains (1 and 2) Individual Practices, (3) How to Run a Binder, and (4) Index.

The volume contains a considerable quantity of useful and interesting information in small compass and in fairly simple language. It will be found of much value to the farmers of the western United States. It is probable, however, that those who believe that the farmer, equally with other workers, should have information presented to him in a clear, logical and accurate manner will be somewhat disappointed in the book. The author necessarily has written from a somewhat local viewpoint and, therefore, has frequently cited local results in such a manner as to imply their wide application in practice. There is a distinct lack of logical sequence of arrangement of matter in many places, as, for example, the paragraphs in chapter II, headed "Habits and Structure of Plant," "Flower and Fruit," "Germination and Roots," "Stooling," "The Grain," etc. Headings of obviously different rank appear in the same type throughout the book. At times the construction is so involved that the reader is compelled to discover its meaning in spite of, rather than because of, the language used. Happily, the unfortunate features, as a whole, are matters of illogical arrangement and loose and confusing statement, rather than of inaccurate statement, though the latter are not wanting. For example, the subspecies or so-called species of wheat are discussed under the heading "Types and Genera" (p. 21); Fultz wheat is described as bearded (p. 22); the so-called "Velvet Chaff" is called a soft wheat (p. 23); stacking in barns is indicated as a common practice (p. 72); the bran is apparently referred to as the hull (p. 90); the so-called spreading winter wheats are declared not suitable for extensive dry-farmed areas (p. 131); and others of this character.

The book also contains frequent indications of apparently hasty and careless work on the part of both author and editor. For instance, some 47 examples of incorrect spelling and grammar, and faulty presswork, were noted in a cursory reading of 173 pages.—C. R. B.

REPORT OF THE SECRETARY FOR 1914.

There are but few noteworthy features in the work and results of the current year. The chief advance has been the change in the frequency of issue of the Journal from quarterly to bimonthly. As last year, the Society has steadily increased in membership without special attention being given to the matter. The work of the office, as represented by the number of letters written and the number of manuscripts edited, has sensibly increased over that of 1913. Following the regular report is a summary of the results of certain activities during the seven years since the Society was founded.

Again it is a pleasure to record the efficient service of Miss L. M. Fissel and, in addition, that of Mr. Karl H. Townsend and Miss J. B. Taylor, as also the continued assistance of Professor C. V. Piper.

1. FUNDS COLLECTED BY THE SECRETARY.

The following is a classified list of the funds which have been received by the Secretary chiefly from dues of new members (see attached list of names) and the sale of the *Proceedings* and Journal. All these have been transmitted to the Treasurer and are included in his annual report.

Classified Receipts and Disbursements, November 1, 1913–October 31, 1914.

Receipts.

To dues collected (itemized list appended):			
16 new members for 1913	at $2.00	$32.00	
49 new members for 1914	at 2.00	98.00	
1 new member for 1914	at 1.50	1.50	
26 local members for 1914	at .50	13.00	$144.50
To *Proceedings* and Journal sold:			
4 copies of Volume 1	at $1.00	$ 4.00	
2 copies of Volume 1	at 1.25	2.50	
6 copies of Volume 1	at 2.00	12.00	
6 copies of Volume 2	at 1.00	6.00	
4 copies of Volume 2	at 1.50	6.00	
2 copies of Volume 2	at 2.00	4.00	
4 copies of Volume 3	at 1.00	4.00	
3 copies of Volume 3	at 1.50	4.50	
7 copies of Volume 3	at 2.00	14.00	
4 copies of Volume 4	at 1.00	4.00	
1 copy of Volume 4	at 1.25	1.25	
11 copies of Volume 4	at 2.00	22.00	
2 copies of Volume 4	at free	....	
3 copies of Volume 5	at 1.00	3.00	
9 copies of Volume 5	at 2.00	18.00	
9 copies of Volume 6	at 2.00	18.00	
4 parts of Volume 5	at .60	2.40	$125.65
			$270.15

Disbursements.

Jan. 29, 1914, by check to Treasurer Roberts	$ 52.50	
Feb. 16, 1914, by check to Treasurer Roberts	69.95	
Apr. 1, 1914, by check to Treasurer Roberts	73.20	
Oct. 31, 1914, by check to Treasurer Roberts	74.50	$270.15
Balance on hand Nov. 1, 1914		$ 0.00

2. MEETINGS.

Three meetings have been held during the current year, namely, two special meetings and the present annual meting.

The first special meeting was held in Dallas, Texas, on February 18, during the Sixth National Corn Exposition. Vice-President Montgomery presided, 4 papers were presented, and about 35 persons were in attendance.

The second special meeting was held at the Hays Branch Experiment Station, Hays, Kansas, on July 8–10, in connection with the ninth annual meeting of the Great Plains Cooperative Association. No attempt was made to separate the papers or the programs of the two organizations. About 25 papers were presented and 71 persons were in attendance. More than half of the speakers and more than half of the attendants were members of this Society.

No meeting was held in connection with the sessions of the Sixth Graduate School of Agriculture at Columbia, Mo., in July. However, as noted in the JOURNAL (p. 136), this Society was represented by the four lecturers in agronomy and the two leaders of conferences on methods of agronomic teaching.

The present gathering is the Seventh Annual Meeting of the Society and the fourth held in the City of Washington. There have been 10 papers presented, 3 of which will be published in the final number of the JOURNAL for this year. Every paper on the program was presented and also two additional ones. An average of 75 persons, of whom 55 were members, have attended each session. A total of 66 members was present at the meeting.

3. MEMBERSHIP.

It is gratifying to report, as last year, that the membership of the Society is steadily increasing. The aims and achievement of the Society are apparently sufficiently attractive to the increasing numbers of American agronomists to cause a fairly steady stream of applicants for membership throughout the year. It is quite probable, however, that a large and helpful increase in membership would result if a definite request were made of one or more workers, in each of the agronomic departments of our colleges and stations, personally to visit and solicit the interest of members of the department staff who are not members of the Society. This suggestion is freely commended to the incoming Secretary.

CHANGED ADDRESSES.

From December, 1913, to October, 1914, inclusive, 29 of the changes of address recorded in the JOURNAL were caused by changes of position. In this current number 7 more such changes are given, making a total of 36 for the year, or 9 percent of the membership involved. During 1913, there were 60 such changes, representing 17 percent of the membership.

The following is a complete list of those whose addresses are changed in the present issue.

Churchill, O. O.
Free, E. E.
Hopkins, Cyril G.
Laude, Hilmer H.
Worrall, Lloyd.
McCall, Arthur G.
Westgate, J. M.

New Members.

The total membership at the end of 1913 was 349. To October 31, new members to the number of 58 have joined the Society. During the same period, 3 have resigned and 18 (one omitted from the March–April Journal) have allowed their membership to lapse through nonpayment of dues. Of these, however, 2 have been reinstated, leaving a net loss of 19, and a present membership of 388. However, several new members for 1914 will be received at this meeting and the total swelled probably to 400 or more.[1]

Below is given a list of the names of new members for 1914. Those marked with the asterisk have joined since the previous issue of the Journal. The addresses of all new members will be found in the address list of members which follows. The name of the reinstated member is appended also.

New Members for 1914.

App, Frank
Arny, A. C.
Atwater, Christopher G.*
Ballard, R. L.
Bear, F. E.
Bonazzi, Augusto
Bonnett, R. K.
Brunson, A. M.
Burr, W. W.
Carr, R. H.
Cassel, C. E.
Cox, J. F.
Dickenson, R. W.
Dobbs, W. F.
Doneghue, R. C.
Dunton, Leila
Fred, E. B.
Fox, D. S.
Gentle, G. E.
Gile, P. L.
Grace, O. J.
Grantham, G. M.
Grimes, W. E.
Hastings, S. H.
Hanger, W. E.
Hechler, W. R.*
Hershberger, Jos. P., Jr.*
Hudelson, R. R.
Hughes, H. D.*
Hyslop, G. R.
Johnson, F. W.
Kaden, F. C.*
Keim, F. D.
Kellerman, Karl F.*
Kelley, W. P.
Kennard, F. L.
Kinnaird, R. A.
LaTourette, L. D.
Lowry, M. W.
McClelland, C. K.
McIntire, W. H.
McMurdo, G. A.
McNeely, L. R.
Millar, C. E.
Miller, E. C.
Myer, D. S.
Olson, M. E.
Peters, D. C.
Pope, M. N.
Robb, N. S.*
Robertson, A. D.
Schoonover, W. R.
Sieglinger, J. B.
Smith, R. S.
Southwick, B. G.
Starr, S. H.*
Suddath, R. O.
Thompson, G. E.
Throckmorton, R. I.
Tucker, G. M.
Voorhees, J. H.
Wehrle, L. P.
Westbrook, E. C.
Wilson, B. S.
Yoder, Malon
Zerban, F. W.

Reinstated Member.

Derr, H. B.

Address List of Members.

Abbott, John B., Purdue Experiment Station, La Fayette, Ind.
Adams, E. L., U. S. Cereal Field Station, Biggs, Calif.
Adams, Geo. E., Experiment Station, Kingston, R. I.

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[1] Since the above was written 8 new members for 1914 have been received and one more lapsed member reinstated, making a total membership for 1914 of 397.

Aicher, L. C., Experiment Substation, Aberdeen, Idaho.
Allen, Edward R., Experiment Station, Wooster, Ohio.
Allyn, Orr M., Experiment Station, Urbana, Ill.
Alway, F. J., Dept. Soils, University Farm, St. Paul, Minn.
App, Frank, Rutgers College, New Brunswick, N. J.
Arny, A. C., Dept. Agronomy, University Farm, St. Paul, Minn.
Atkinson, Alfred, Experiment Station, Bozeman, Mont.
Atwater, Christopher G., Agr. Dept., Am. Coal Products Co., 17 Battery Place New York, N. Y.
Ayrs, O. L., Care Tenn. Coal, Iron & R. R. Co., Birmingham, Ala.
Babcock, F. R., Experiment Substation, Williston, N. Dak.
Ball, Carleton R., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Ball, Elmer D., Experiment Station, Logan, Utah.
Ball, Wilbur M., Consulado-General E. U., Buenos Aires, Argentina, S. A.
Ballard, Robert L., Coöperative Demonstration Work, Ashburn, Ga.
Barker, Joseph F., Experiment Station, Geneva, N. Y.
Barre, H. W., Clemson College, Clemson, S. C.
Bartlett, Harley Harris, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Bear, Firman E., Agricultural College, Univ. of W. Va., Morgantown, W. Va.
Beaumont, A. B., Dept. Soil Tech., Cornell University, Ithaca, N. Y.
Bell, Henry G., Nat'l Fertilizer Asso., Room 919, Postal Tel. Bldg., Chicago, Ill.
Bell, James M., Univ. of North Carolina, Chapel Hill, N. C.
Bennett, Hugh H., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
Benzin, Basil M., Imp. Dept. of Agriculture, Petrograd, Russia.
Bergh, Otto I., Experiment Station, Grand Rapids, Minn.
Bizzell, James A., Dept. Soil Tech., Cornell University, Ithaca, N. Y.
Bolley, H. L., Experiment Station, Agricultural College, N. Dak.
Bonazzi, Augusto, Experiment Station, Wooster, Ohio.
Bonnett, Robert K., Agricultural College, Manhattan, Kans.
Boss, Andrew, Experiment Station, University Farm, St. Paul, Minn.
Bouyoucos, G. J., Experiment Station, East Lansing, Mich.
Boving, Paul A., Macdonald College, P. Q., Canada.
Bower, H. J., Extension Dept., Parsons, Kans.
Bowman, Albert E., U. S. Office Farm Management, Laramie, Wyo.
Bracken, John, Saskatchewan Univ., Saskatoon, Sask., Canada.
Briggs, Lyman J., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Brodie, D. A., Office Farm Management, U. S. Dept. Agr., Washington, D. C.
Brown, B. E., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
Brown, C. B., Experiment Station, Dalhart, Texas.
Brown, J. Stanford, R. F. D. Box No. 38, Blackhall, Conn.
Brown, P. E., Iowa State College, Ames, Iowa.
Brunson, A. M., Experiment Station, Urbana, Ill.
Buchanan, John, Dept. Agron., Iowa State College, Ames, Iowa.
Buckman, H. O., Dept. Soil Tech., Cornell University, Ithaca, N. Y.
Buell, T. W., Experiment Substation, Krum, Texas.
Bull, C. P., Experiment Station, University Farm, St. Paul, Minn.
Burgess, James L., State Dept. of Agriculture, Raleigh, N. C.
Burgess, P. S., Experiment Station, Berkeley, Calif.
Burnett, L. C., Dept. Agron., Iowa State College, Ames, Iowa.

Burr, W. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Butler, Ormond R., Experiment Station, Durham, N. H.
Call, L. E., Experiment Station, Manhattan, Kans.
Cameron, Frank K., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
Cardon, P. V., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Carleton, M. A., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Carlyle, Alex., Experiment Farm, Vermilion, Alta., Canada.
Carr, Ralph H., 24 N. Salsbury Street, La Fayette, Ind.
Carrier, Lyman, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Carroll, J. S., 1212 Empire Bldg., Atlanta, Ga.
Cassel, Charles E., Tribune Substation, Tribune, Kans.
Chambliss, Charles E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Champlin, Manley, Experiment Station, Brookings, S. Dak.
Chappelear, Geo. W., Miller Manual Labor School, Miller School, Va.
Chilcott, E. F., Woodward Field Station, Woodward, Okla.
Childs, R. R., College of Agriculture, Athens, Ga.
Churchill, O. O., Dept. Agronomy, Agricultural College, N. Dak.
Clark, Charles F., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Clark, Charles H., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Clark, J. Allen, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Clinton, L. A., Farm Management Demonstrations, U. S. Dept. Agr., Washington, D. C.
Clothier, R. W., 209 College Avenue, Ithaca, N. Y.
Coffey, G. N., Experiment Station, Wooster, Ohio.
Cole, John S., Care Forest Service, Majestic Bldg., Denver, Colo.
Coleman, L. C., Director of Agriculture, Bangalore, Mysore State, India.
Conn, H. J., State Experiment Station, Geneva, N. Y.
Conner, A. B., Experiment Station, College Station, Tex.
Conner, S. D., Dept. Chemistry, Purdue University, La Fayette, Ind.
Cory, Victor L., Lubbock Substation, Lubbock, Tex.
Cox, Joseph F., Agricultural College, East Lansing, Mich.
Crabb, Geo. A., College of Agriculture, Athens, Ga.
Craig, C. E., Escola du Ingenharia, Porto Alegre, Rio Grande do Sul, Brazil, S. A.
Critz, Hugh, Starkville, Miss.
Cromer, Otis, Experiment Station, La Fayette, Ind.
Cron, A. B., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Crosby, M. A., Office Farm Management, U. S. Dept. Agr., Washington, D. C.
Cunningham, C. C., Experiment Station, Manhattan, Kans.
Cutler, G. H., Saskatchewan University, Saskatoon, Sask., Canada.
Davis, R. O. E., Bur. Soils, U. S. Dept. Agr., Washington, D. C.
Davison, W., Dept. Agr., Charlottestown, P. E. I., Canada.
Deatrick, Eugene P., 130 Dryden Road, Ithaca, N. Y.
Delwiche, E. J., 1221 Chicago Street, Green Bay, Wis.
Derr, H. B., Agricultural Advisor, Sikeston, Mo.
DeTurk, Ernest, Experiment Station, State College, Pa.
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4. JOURNAL AND PROCEEDINGS.

In accordance with the recommendations made by the editor at the last annual meeting, the JOURNAL has been changed from a quarterly to a bimonthly. Just how much more attractive the increased frequency of issue might have been will never be known because of the delay in issuing the various numbers. These unfortunate delays have been due largely to delays in obtaining suitable material for publication. The supply finally obtained has been about sufficient for the issues planned but it has arrived about three months behind the need for it throughout the year. The appearance of the third number was retarded somewhat, it is true, by the absence of the editor on field service, but this delay became possible only because the lack of material prevented an earlier beginning of proof-reading. However, three numbers have been issued, a double number is in press, and this meeting should provide enough material for the sixth and final number.

There can be but little doubt that the founding by the U. S. Department of Agriculture of the *Journal of Research* and the extension of its privileges to station workers is destined to further affect the volume of contributions to our JOURNAL, as well as to other media for the publication of scientific results.

DISPOSAL OF PUBLICATIONS.

In Table 1 will be found full data on the disposal of the *Proceedings* and JOURNAL during the year ending October 31.

TABLE 1.—*Data Showing the Original Edition of Each Volume of the Proceedings and Journal, the Distribution Made Previous to and During 1914, and the Number of Copies Remaining in Stock.*

Edition Printed, Disposition of Copies and Number Remaining.	Volumes.					
	1	2	3	4	5	6
Edition printed	501	517	516	514	750	750
Previously accounted for	319	321	348	354	...	...
Distributed to members, 1913–1914	...	...	...	...	349	396
Distributed to subscribers, 1913–1914	...	...	...	...	43	43
Sample copies	...	...	...	...	196	26
Sold, 1914	12	12	14	16	12	9
Samples to foreign agent	6	6	6	6	6	6
Number unaccounted for	...	2	...	2	...	...
Replacing lost copies	...	...	...	2	...	...
Total copies distributed	337	341	368	380	606	480
Difference	164	176	148	134	144	270
Sold on credit orders	1	1	3	3	3	2
Copies in stock	163	175	145	131	141	268

The two copies each of Vols. 2 and 4, listed as "Unaccounted for," probably indicate miscounts made previously rather than actual loss of volumes, as it is known that one or two copies sent as samples to printers, when asking for printing estimates, were not returned. This probably accounts also for the three copies of Vol. 3, similarly listed last year.

The figures show a total of 75 volumes sold, or an average of 12.5 copies of each volume issued to date. The number sold could have been increased had more attention been given it. In the early summer, arrangements were made with G. E. Stechert & Co., of New York, to act as foreign agents for our publications. A set of six copies of each volume was sent them as advertising samples. The outbreak of the European war has doubtless made impossible the sale of such material in most of the scientific institutions which otherwise might have become customers.

5. MINUTES OF THE ANNUAL MEETING.

WASHINGTON, D. C., NOVEMBER 9–10, 1914.

First Session, Monday Afternoon, November 9.

The meeting was called to order at 1:45 p.m. by President Piper and the presentation of papers on the regular program was taken up, as follows:

1. Unit-Acre Platting Systems, by Director B. Youngblood and Prof. A. B. Conner.
2. The Origin of "Niter Spots" in Certain Western Soils, by Dr. Robert Stewart.
3. On Naming Varieties, by Prof. E. G. Montgomery (read by Dr. C. E. Leighty in the absence of the author).
4. Potato Seed Inspection and Certification (illustrated), by Mr. W. A. Orton.
5. The Effect of Different Methods of Preparing a Seed-bed for Winter Wheat on Yield, Soil Moisture and Nitrates (illustrated), by Prof. L. E. Call.

The paper by Dr. C. B. Lipman not being present, it was passed until the next session.

The reading of the papers being concluded President Piper announced two special committees as follows:

NOMINATING COMMITTEE.

W. M. Jardine, *chairman;* T. Lyttleton Lyon and Geo. N. Coffey.

AUDITING COMMITTEE.

George Livingston, *chairman*, and Robert Stewart.

After announcements by Mr. W. W. Burr about the agronomists' dinner; by Treasurer Roberts concerning unpaid dues; by Secretary Ball regarding registration, applicants for membership, and handing in papers for editing; and by President Piper with reference to the next session, the session adjourned. Seventy-four persons were present, of whom 55 were members of the Society.

Second Session, Tuesday Afternoon, November 10,

The meeting was called to order by President Piper at 1:45 p.m. The reading of papers was resumed, as follows:

6. Soil Moisture Relations, by G. S. Fraps.
7. Relation of Chemical Composition of Soil Fertility, by G. S. Fraps.
8. Notes on Australian Agriculture, by Dr. L. J. Briggs.
9. The Solids of Smelter Wastes and Plant Growth, by Dr. C. B. Lipman.

This ended the presentation of papers, except the presidential address. The session, at which about 80 persons were present, then proceeded to the consideration of business.

(*Business Session.*)

On motion the minutes of the last annual meeting were approved as printed in the JOURNAL (5: 246–48) for October–December, 1913.

The report of the Secretary was read and, on motion, accepted.

The report of the Treasurer was read and, on motion, accepted.

The report of the Auditing Committee was read by Dr. Stewart and, on motion, accepted.

On motion, the thanks of the Society were given to the Secretary and Treasurer for efficient service.

The report of the Executive Committee was read by the Secretary and adopted by the Society, on motion.

The report of the committee on soil classification and mapping was read by the chairman, Dr. G. N. Coffey. After discussion by Dr. C. A. Mooers, Dr. J. G. Lipman, Prof. M. A. Carleton, Prof. Geo. Roberts, Dr. Oswald Schreiner, Prof. C. F. Marbut, Prof. E. O. Fippin, and Prof. W. M. Jardine, it was moved by Dr. Lipman that the report be received as a report on progress and the committee continued. The motion carried.

For the committee on agronomic terminology, the chairman, Mr. C. R. Ball, reported that, owing to pressure of secretarial work, little progress had been made and outlined briefly the proposed plan of future action.

The report of the committee on standardization of field experiments was read by the chairman, Prof. C. V. Piper, and accepted, after discussion by Dr. T. L. Lyon, Professor C. V. Piper, Dr. Oswald Schreiner, Dr. H. L. Shantz, and Prof. W. M. Jardine.

On motion by Dr. Lyon the first resolution presented by the committee on standardization of field experiments was amended by omission of the language limiting size of plats. On motion the amended resolution was adopted (for text thereof see reports of committees).

On motion by Dr. C. B. Lipman the second resolution of this committee was adopted.

No report from the committee on varietal nomenclature was present, other than Prof. Montgomery's paper.

The nominating committee, by Chairman Jardine, reported the following nominees for offices in the Society for the year 1915:

President, Dr. C. E. Thorne, Ohio Experiment Station;
First Vice-President, Dr. L. J. Briggs, U. S. Dept. of Agr.;
Second Vice-President, Prof. Alfred Atkinson, Montana Expt. Station;
Secretary, Mr. C. W. Warburton, U. S. Dept. of Agr.;
Treasurer, Prof. Geo. Roberts, Kentucky Experiment Station.

The committee also made the following recommendation:

"Your committee also wishes to suggest to the executive committee the desirability of appointing as editor some person other than the secretary in order to relieve the secretary of a part of his present duties, now including the editorial responsibility, which work in itself involves an unusual amount of very careful attention and requires much time."

(Signed) W. M. Jardine,
T. L. Lyon,
Geo. N. Coffey,
Committee.

On motion, the Secretary was instructed to cast the ballot of the Society for the nominees and, this being done, they were declared elected to the respective offices.

On motion of Prof. Fippin the thanks of the Society were tendered to the retiring officers and especially to the Secretary for valued and efficient service.

Prof. J. H. Gilmore presented the desirability of holding the next annual meeting of the Society on the Pacific Coast in connection with the meeting of Section M of the American Association for the Advancement of Science.

On motion of Dr. C. B. Lipman the Society expressed its thanks to the management of the New Willard Hotel for courteous hospitality in furnishing a meeting place for the sessions of the Society.

The Society then adjourned to meet at 8 o'clock p.m.

Third Session, Tuesday Evening, November 10.

This session, held jointly with the Society for the Promotion of Agricultural Science, for the presentation of presidential addresses, was called to order at 8:15 p.m. by Dr. W. J. Beal, presiding, with about 200 persons present.

After the address by Dr. H. J. Waters, President of the Society for the Promotion of Agricultural Science, the tenth and last paper on the program, the address of the retiring president, Prof. C. V. Piper, entitled "Fundamental Principles in Agronomy," was delivered and the Society adjourned, *sine die*.

6. SUMMARY OF THE ACTIVITIES OF THE SOCIETY.

With this meeting the writer completes five years of consecutive service as secretary of the Society and editor of its publications. Since it is necessary that the period of service now terminate, it may be considered worth while to summarize some of the activities of the Society during the seven years of its existence. These data may have not only interest now but also value hereafter when the historical record of the infant Society is desired. The data are arranged under the following headings: (1) Meetings, (2) Membership, and (3) Publications.

1. Meetings.

In Table 2 is given a summary of data concerning the meetings held by the Society in the years 1908–1914, inclusive. From these data it is seen that 14 meetings have been held, or an average of 2 each year. Of the total number, 7 have been annual and 7 special meetings. All of the former have been held in connection with the meetings of the Association of Agricultural Colleges and Experiment Stations, and 4 of them in Washington, D. C.

It is interesting to note that a total of 199 papers have been presented in these 14 meetings in 7 years, or an average of 14.2 at each meeting and 28.4 in each year. Of these 199 papers, 104 have been published in the *Proceedings* and JOURNAL.

TABLE 2.—*Summary of the Date, Place, Character and Affiliation of the Meetings Held During 1908–1914, Inclusive, with Number of Papers Presented at Each Meeting and the Number of These Published by the Society.*

Date.	Place.	Character.	In Connection With	Papers.	
				Read.	Published.
1908 Dec. 31, '07–Jan. 1	Chicago, Ill.	Organization	A.A.A.S.	10	1
July 9–11	Ithaca, N.Y.	Special	Grad.Sch.Agr.	14	7
Nov. 17–18	Washington, D.C.	Annual	A.A.C. & E.S.	20	10
1909—Dec. 7–8	Omaha, Nebr.	Annual	Natl. Corn Expo.	25	21
1910—Nov. 14–15	Washington, D.C.	Annual	A.A.C. & E.S.	20	15
1911—Nov. 13–14	Columbus, O.	Annual	A.A.C. & E.S.	16	9
1912 July 11	Lansing, Mich.	Special	Grad. Sch. Agr.	19	13
Nov. 11–12	Atlanta, Ga.	Annual	A.A.C. & E.S.	16	6
1913 Jan. 27–28	Columbia, S.C.	Special	Natl. Corn Expo.	8	4
Aug. 20–22	North Platte, Nebr.	Special	Gt. Plains Co-op. Assn.	10[1]	3
Nov. 10–11	Washington, D.C.	Annual	A.A.C. & E.S.	12	8
1914 Feb. 18	Dallas, Tex.	Special	Natl. Corn Expo.	9	3
July 8–10	Hays, Kans.	Special	Gt. Plains Coop. Assn.	10[1]	1
Nov. 9–10	Washington, D.C.	Annual	A.A.C. & E.S.	10	3
			Total.	199	104

[1] The papers of the two organizations were not separated and this number is estimated.

2. MEMBERSHIP.

From a study of the figures given in Table 3, it will be seen that 456 members have joined the Society since it was established. Of this number, one has been lost by death, 12 by resignation, and 56 by lapsing of membership through nonpayment of due. Of these, 10 have been reinstated, thus giving a net loss of 59 members and a present membership of 397. The average rate of gain has been 67 members each year. For the last 5 years it has been 61.6 members annually. The average annual loss has been 8.43 members during the 7 years, or 11.6 members annually during the last five years. These figures represent an annual loss of 1.85 percent of the membership during the 7-year period and a loss of 4.54 percent during 1914.

TABLE 3.—*Statistics of Membership of the Society, During the Seven Years, 1908–1914, Inclusive.*

Year.	Accessions.		Losses.				Net Membership.
	New.	Reinstatement.	Death.	Resignation.	Lapsed.	Net.	
1908	121	0	0	0	0	0	121
1909	26	0	1	0	0	1	146
1910	46	0	0	3	17	20	172
1911	71	0	0	2	5	7	236
1912	62	5	0	1	7	3	295
1913	64	2	0	3	9	10	349
1914	66	3	0	3	18	18	397
	456	10	1	12	56	59	

3. PUBLICATIONS.

At the second annual meeting of the Society, held at Omaha, Nebraska, December 7–8, 1909, it was voted that an editing committee of five be appointed, the secretary of the Society to be, *ex officio,* secretary of the committee, and that the *Proceedings* of the Society be published, in as large an edition as was possible with the funds in hand. C. V. Piper was made chairman of the editing committee and C. R. Ball, newly elected secretary of the Society, became *ex officio* its secretary. It has been the pleasure of the writer, therefore, to supervise the publications of the Society from their beginning until the present time.

During these five years, six volumes have been published; four volumes of the *Proceedings,* for the years 1909–1912, inclusive, succeeded by the JOURNAL, of which volumes 5 and 6, for the years 1913 and 1914, have already been issued. In Table 4 are shown the number, nature, and size of the volumes and of the included papers, for the entire series.

TABLE 4.—*Showing the Number, Character, and Size of the Volumes of the Proceedings and the Journal, and of the Included Papers.*

Vol.	Year Covered.	Character and Frequency of Issue.	Papers.			Pages.	Plates.	Text Figures.
			Long.	Brief.	Total.			
1	1908–09	Proceedings, annual, clothbound	29	10	39	238	0	3
2	1910	“ “ “	12	4	16	154	6	22
3	1911	“ “ “	13	1	14	286	4	51
4	1912	“ “ “	14	6	20	160	0	8
5	1913	Journal, quarterly, paper	21	12	33	256	6	15
6	1914	Journal, bimonthly, paper	23	7	30	294	6	25
			112	40	152	1,388	20	124

Of the 152 papers published in the 6 volumes, 101 have been presented before the Society at its various meetings, and 51 have been contributions from other sources.

The four volumes of clothbound *Proceedings* were issued in editions of about 500 copies each. For the two volumes of the JOURNAL the edition has been increased to 750 copies, owing to the increasing membership of the Society and the use of sample copies for sending to prospective members. Table 5 shows for each volume, the edition printed, the annual distribution made, and the number of complete volumes remaining in stock. In the case of the issues of the JOURNAL, the number in stock is the actual number of complete volumes. Since the free distribution of sample copies, as well as the sale, was not the same for all numbers, it follows that the quantity of some numbers remaining is greater than the quantity of complete volumes.

TABLE 5.—*Data Showing the Editions Printed of Each Volume of the Proceedings and the Journal, the Distribution Made, and the Number of Complete Volumes Remaining in Stock, October 31, 1914.*

Distribution.	Volumes.					
	1	2	3	4	5	6
Edition printed	501	517	516	514	750	750
Number distributed to members	129	168	234	292	359	396
Number sold in 1911	31	...	...	...	...	...
Number sold in 1912	94	89	41	...	...	...
Number sold in 1913	61	61	64	30	3	...
Number sold in 1914	12	12	14	16	12	9
Number library subscriptions	...	...	...	31	43	43
Number distributed free	1	1	1	1	1	1
Number lost in mails	1	2	3	2	1	...
Number defective	2	...	2	...	...	...
Number unaccounted for	...	2	3	2	...	...
Number samples to agent	6	6	6	6	6	6
Number samples to non-members	...	...	...	...	196	26
Total number distributed	337	341	368	380	606	481
Number in stock	164	176	148	134	144	269

The number of copies in excess of 500 in the editions of volumes 2–4, inclusive, were furnished without charge by The New Era Printing Co., which has had the contract for printing and binding. The supply of publications remaining in stock is a clear asset of the Society, since the membership fees and sales from the beginning have considerably more than covered the cost of publication.

In Table 6 are shown the amounts received from the sale of publications during each year since the sale began, and the total amount received during the four years. These data cover not only the receipts from the disposal of volumes listed as "sold" in Table 5, but also for those listed as "distributed to subscribers," so far as payment has been made to the treasurer for the latter.

TABLE 6.—*Funds Received from Sale of Proceedings and Journal, 1911–1914, Inclusive.*

Year.	By Secretary.	By Treasurer.	Total.
1911	60.00	2.00	62.00
1912	367.25	0.00	367.25
1913	308.60	81.50	390.10
1914	125.65	154.00	279.65
Total	861.50	237.50	1,099.00

REPORT OF THE TREASURER.

FROM NOVEMBER 10, 1913, TO NOVEMBER 9, 1914.

Receipts.

Balance on hand November 10, 1913		$ 377.34
From the Secretary, C. R. Ball, per his statements Nos. 1–4		270.15
Membership fees received:		
For 1912	$ 2.00	
For 1913	148.00	
For 1914	518.00	
For 1915	8.00	$ 676.00
Receipts from Libraries for *Proceedings:*		
For Volume 4	$ 4.00	
For Volume 5	72.00	
For Volume 6	78.00	$ 154.00
Total receipts		$1,477.49

1913.	Disbursements.	Voucher No.	
Nov. 29.	L. M. Thayer, printing	31	$ 3.50
Nov. 29.	C. R. Ball, Secretary's expenses	32	6.93
Dec. 10.	New Era P't'g Co., printing JOURNAL, 5^{1-2}	33	287.98
Dec. 10.	L. M. Thayer, printing	34	9.50
Dec. 10.	Maurice Joyce Eng. Co., halftones	35	16.90
Dec. 17.	Ky. State University Press, printing	36	5.00
Dec. 17.	Geo. Roberts, reimbursement for stamps, and blank book	37	8.50
Dec. 17.	Maurice Joyce Eng. Co., halftones	38	8.00
1914.			
Jan. 10.	New Era P't'g Co., printing JOURNAL, 5^3	39	137.05
Jan. 31.	Maurice Joyce Eng. Co., halftones	40	2.00
Feb. 27.	L. M. Thayer, printing	41	2.75
Mar. 5.	C. R. Ball, Secretary's expenses	42	11.95
Mar. 19.	L. M. Thayer, printing	43	2.50
Mar. 19.	New Era P't'g Co., printing JOURNAL, 5^4	44	183.24
Apr. 6.	C. R. Ball, Secretary's expenses	45	8.13
Apr. 16.	Maurice Joyce Eng. Co., halftones	46	2.00
May 22.	L. M. Thayer, printing	47	5.50
May 22.	New Era P't'g Co., printing JOURNAL, 6^1	48	117.23
May 22.	Maurice Joyce Engraving Co.	49	8.90
June 20.	Maurice Joyce Engraving Co.	50	12.00
June 30.	New Era P't'g Co., printing JOURNAL, 6^2	51	117.40
Aug. 7.	C. R. Ball, Secretary's expenses	52	7.42
Sept. 26.	Stamps	53	10.00
Oct. 19.	C. R. Ball, Secretary's expenses	54	23.75
Oct. 27.	New Era P't'g Co., printing JOURNAL, 6^3	55	100.98
Nov. 2.	L. M. Thayer, printing	56	3.50
Nov. 3.	Maurice Joyce Eng. Co.	57	14.82
	Total disbursements		$1,117.43
	Balance November 9, 1914		360.06
			$1,477.49

Financial Standing of Membership.

Number of members paid for 1914	312
Number of members not paid for 1914	76
Number of members paid for 1915	4
Number of members in good standing	388

GEO. ROBERTS,
Treasurer.

AUDITING COMMITTEE'S STATEMENT.

We have examined the accounts and vouchers of the treasurer and found them correct as reported.

GEO. LIVINGSTON,
ROBERT STEWART,
Auditing Committee.

REPORTS OF COMMITTEES.

The reports of the two special committees, on audit of accounts, and on nominations, are found elsewhere. The report of the auditing committee is appended to the report of the Treasurer while that of the committee on nominations, including their recommendation, appears at the proper place in the minutes of the business session.

The reports of three standing committees, namely, on soil classification and mapping, on standardization of field experiments, and an agronomic terminology, appear herein.

REPORT OF THE EXECUTIVE COMMITTEE.

A meeting of the Executive Committee was called at Washington, D. C., November 12, 1913, by President C. V. Piper.

On motion the Secretary was authorized to arrange for the handling of foreign subscriptions through suitable agents.

On motion it was ordered that the JOURNAL be issued bimonthly in 1914.

On motion an edition of 600 copies, or 700, if not too great an additional expense, was ordered.

On motion the matter of reviews in the JOURNAL was referred to the Board of Editors.

On motion the Secretary was authorized to spend a reasonable sum on clerk hire.

On motion the Secretary was instructed to investigate the matter of suitable headquarters for the Society and report to the Executive Committee.

On motion the Secretary was instructed to obtain from the Society a referendum vote on the question of increased dues before the next annual meeting.

On motion the Secretary was authorized to arrange for regional meetings of the Society at the National Corn Exposition and the Great Plains Coöperative Association; also at the meeting of New England agronomists, if a program meeting is assured, and at the Graduate School of Agriculture if arrangements can be made for an open date for two sessions and a definite part in the program of the School.

On motion it was decided that a standing committee on nominations should be appointed, the same to present the names of one or more nominees for each office, these names to be published in the JOURNAL preceding the date of annual meeting and voted upon at said meeting.

A true copy.

C. R. BALL,
Secretary.

PROGRESS REPORT OF THE COMMITTEE ON SOIL CLASSIFICATION AND MAPPING.

INTRODUCTION.

The further extension of investigations into the principles and practices of crop production and related matters has made more apparent the necessity for accurate information concerning the character of the soil in different parts of the country. To supply this information soil surveys have been organized and are progressing at an increasing rate and are being undertaken by a larger number of institutions.

Definite knowledge in regard to the nature of the soil is so fundamental that uniformity in classification and mapping is very desirable in order that the results may be as nearly comparable as possible.

With these facts in mind and in order to assist in bringing about the desired results, a resolution was adopted by this Society at its meeting in Ithaca, N. Y., in July, 1908, looking to the creation of a committee on soil classification and mapping, and an organization committee of five members was appointed by the president.

At the annual meeting, in Washington, in November, 1908, this organization committee presented a report which, as adopted, is as follows:

"Your committee recommends that a committee of fifteen persons, qualified for the work, shall be appointed by the Executive Committee of this Society to assist in bringing about greater uniformity in soil classification and nomenclature. Of this committee five shall serve for one year, five for two years, and five for three years.

"The committee shall, after conference with the authorities having charge of soil surveys conducted by official institutions in the United States and Canada, draw up a report and submit the same to the action of this Society.

"The committee may, from time to time, change or amend its actions, but its reports and amendments must be adopted by a majority of the members present at any meeting of the Society, in order that such action shall be considered the official action of this Society.

"Your committee believes that, while the action of the Society in these matters will not be binding upon any of the institutions conducting soil surveys, it will carry sufficient moral force to make such action practically official, and that if the plans adopted be practicable and of general application they will be put into effect by all organizations conducting soil surveys in the United States and Canada."

The committee so appointed, consisting of fifteen men identified with soil investigations in the United States and Canada, have held meetings from time to time in connection with the annual meetings of this Society, but, because of the wide separation of the members of the committee, it has not been possible to hold a full meeting at any time, while one-third of the members have not been able to attend any of the meetings. Correspondence has been used also to develop the views, not only of absent members of the committee but of many others whose opinions or criticisms would be of assistance to the committee.

At the Washington meeting of the committee, in November, 1913, a scheme of classification, representing the prevailing opinion of the members present, was drawn up and later submitted to the absent members and also sent to many other investigators along agronomic lines. The major features of the scheme were agreed to by nearly all members of the committee, although objections were made to some of the details. These are briefly summarized at the end of this report.

The aim, as set forth in this scheme, has been to examine the essential factors that produce agricultural differences in soils and to arrange these, so far as possible, in the order of their range of influence, also having in mind the practical identification in the field of the properties concerned.

At the present time it is not considered practicable to define in much detail the characteristics of the factors of separation or set arbitrary limits to particular groups. Local conditions of work and personal viewpoints have brought about local methods of classification and mapping, which can only be brought into conformity by consideration of the larger lines of division, and by prolonged study and discussion of the facts observed in the field by those actually engaged in soil work. It is clearly recognized that it is not always possible to place soil material definitely in the scheme of classification, that differences in judgment will arise concerning material near the boundary of two or more related groups. For this reason the boundary lines are left somewhat flexible.

The following is the system of classification recommended by the committee. However, this should be considered as a report of progress, rather than as a final recommendation, and it is hoped that there will be the freest and fullest discussion in order that the committee may have the advantage of the criticisms of the members of this Society.

The committee recognizes that the general climatic conditions under which a soil is formed have a decided influence upon its properties and that the climate under which a particular soil occurs influences its crop-producing power.

SCHEME OF CLASSIFICATION RECOMMENDED.

I. PRECIPITATION AND HUMIDITY.—Precipitation and humidity are regarded as the broadest basis in the division of soil material. In North America three divisions are recognized, namely: (*a*) humid, (*b*) semi-arid, (*c*) arid, in the sense in which these terms are usually applied, but no attempt is made to specifically define the limits of these divisions.

II. DYNAMIC AGENCIES.—The dynamic agencies by which soil material is formed are recognized as the second factor in the divisions of soils. The agencies are grouped under the following six heads.

(*a*) *Weathering.*—This embraces all those processes commonly recognized as causing the decay of distinctly consolidated rocks, and which have progressed so that important bodies of soil are derived therefrom. The result of this action is commonly known as a *residual* soil.

(*b*) *Biological.*—The accumulation of material directly through the agency of life processes is here included. It gives rise to organic deposits of peat and muck, sometimes known as *cumulose* soils.

(*c*) *Gravity.*—This covers the accumulation of soil material by gravity without the appreciable coöperation of any other force. Such material is usually known as *talus* slopes.

(*d*) *Aqueous* (*Water*).—This covers the sedimentation of soil material in water and includes material transported, sorted and deposited entirely by water. Three phases of such deposits may be recognized:

(1) Alluvial, those laid down by streams.
(2) Lacustrine, those laid down in lakes.
(3) Marine, those laid down in the ocean.

(*e*) *Æolean* (*the Atmosphere*).—This covers the transportation, sorting and deposition of soil material by wind.

(*f*) *Glaciation.*—This covers the pulverization, transportation, mixing, and deposition of soil material by masses of glacial ice, and soils so formed are usually known as *glacial.*

III. LITHOLOGY.—The character of the rock or rocks from which a soil is formed is recognized as the third factor in the division of soils. No action was taken on the types of rocks to be recognized for this purpose but four primary groups are pointed out:

(*a*) Acid crystalline rocks.
(*b*) Basic crystalline rocks.
(*c*) Sandstones, quartzites, shales and slates.
(*d*) Lime rocks, including marl, limestone and marble.

Differences in soil material may arise from difference in the group of rocks from which it is derived or in the proportion derived from different groups of rocks.

IV. SPECIFIC CHARACTERS AND CONDITIONS.—This includes a group of rather closely correlated properties, any one or more of which may serve as the primary basis for the fourth division of soils. These properties and conditions are considered to be:

(*a*) Color—which will most often be the primary factor in this separation and on it strong emphasis is placed since it is especially useful as an indication of differences in soil material.

(*b*) Drainage—the extent and thoroughness of natural drainage.

(*c*) Content of lime carbonate.

(*d*) Content of organic matter.

(*e*) Relation of soil to subsoil. By this last term is meant the variation in the texture and other physical properties within the soil section or profile.

V. TEXTURE.[1]—The texture of the soil material is recognized as the fifth factor in the division of soils. No mathematical limits for the various classes of soil particles were agreed upon:

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[1] In this connection attention is called to the system of grouping soil particles agreed upon at the meeting of the International Commission for the Mechanical and Physical Examination of Soils, at Berlin, on October 31, 1913 (see JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY, 6: 95), which adopted the following divisions:

Particles greater than 20 mm.
Particles from 20 to 2 mm.
Particles from 2 to 0.2 mm.
Particles from 0.2 to 0.02 mm.
Particles from 0.02 to 0.002 mm.
Particles finer than 0.002 mm.

The following main classes of soil are recognized:

(1) Sand.
(2) Sandy loam.
(3) Loam.
(4) Silt loam.
(5) Clay loam.
(6) Clay.

There may be further subdivisions of these classes due to the occurrence of different proportions of the grades of soil material.

Further, any of the classes of soil may be modified by the presence of larger fragments of the parent rock which produce soils that may be designated as:

(1) Gravelly.
(2) Shaly.
(3) Slaty.
(4) Stony.

The names proposed for these several bases, or factors, used in the division of soils are as follows:

I. Precipitation and Humidity—Soil Region.
II. Dynamic Agencies—Soil Province.
III. Lithology—Soil Group.
IV. Specific Characters and Conditions—Soil Series.
V. Texture—Soil Class.

The *Soil Type is the Unit* and may be defined to include all that soil material which is approximately alike in climate, in agency of formation, in source of material, in special properties and conditions and in texture.

Respectfully submitted,

COFFEY, GEORGE N., Ohio Expt. Station, Wooster, Ohio, *chairman.*
FIPPIN, E. O., Cornell University, Ithaca, N. Y., *secretary.*
ALWAY, F. J., Minn. Expt. Station, St. Paul, Minn.
DAY, W. H., Ontario Expt. Station, Guelph, Ont., Canada.
FRAPS, G. S., Texas Expt. Station, College Station, Texas.
KEYSER, ALVIN, Colorado Expt. Station, Fort Collins, Colo.
KILGORE, B. W., North Carolina Expt. Station, Raleigh, N. C.
LOUGHRIDGE, R. H., California Expt. Station, Berkeley, Calif.
MARBUT, C. F., U. S. Bureau of Soils, Washington, D. C.
MOOERS, C. A., Tennessee Expt. Station, Knoxville, Tenn.
MOSIER, J. G., Illinois Expt. Station, Urbana, Ill.
SHUTT, F. T., Central Expt. Farms, Ottawa, Canada.
THORNE, C. E., Ohio Expt. Station, Wooster, Ohio.
WHEELER, H. J., 92 State St., Boston, Mass.
WHITSON, A. R., Wisconsin Expt. Station, Madison, Wis.

COMMENTS BY MEMBERS OF THE COMMITTEE.

In making the report the chairman stated that he regretted to disagree with some important features of the report. He feels that in the scheme of classification too much stress has been laid on the factors which produce differences in soils and too little upon the differences themselves. This fact led to the making of only three divisions from the climatic standpoint although few, if any, differences in soils are more striking and important than that between the black prairie soils (chernozem) and the lighter colored timber soils. This additional division would bring the scheme more in harmony with work in foreign countries, particularly Russia. Peat and muck can best be considered here also, their formation being due to a superhumid condition.

The chairman also disagrees with the committee in regard to the divisions under "Dynamic Agencies," particularly the nomenclature. While he agrees that the division of "residual soils" is proper, he does not think that "weathering" should be applied only to residual soils since it has undoubtedly affected all soils. The other divisions (biological, gravity, aqueous, æolean and glaciation) constitute, with the possible exception of heat and cold, the important agencies of "weathering" and cannot therefore be properly considered as coördinate with weathering. In the opinion of the chairman it would have been much better to have used the commonly accepted subdivision into *residual* and *transported* and then have divided the *residual* into soils from crystalline rocks (igneous and metamorphic), soils from limestones, and soils from sandstones and shales, and the *transported* into the usual divisions.

The chairman is also of the opinion that color should be given a more important place in the scheme since this is one of the most striking and characteristic properties of a soil.

While an advance has been accomplished by the work done, the chairman feels that some modifications in the scheme must be made before it can be of much practical application in soil mapping.

Dr. Alway approves the report in general but suggests that the division as to region should take account of water actually percolated through or into the soil as well as the external climate or humidity.

Professor Fippin would add to the series division the recognition of special chemical properties as one of the factors upon which the series separation should be based. The peculiarities and distribution of plant-food and of alkali salts might here be recognized.

Professor Keyser approves the report in general but thinks minor details, which are not mentioned, probably will need modification.

Professor Marbut thinks some modifications, chiefly in nomenclature, should be made.

Dr. Mooers thinks that the name of the geological formation should be used.

Professor Mosier suggests that peat and muck should receive special mention in classification.

Director Thorne thinks that "weathering" should not be applied to one group only as it affects all soils.

Professor Whitson differs from committee's report on minor points, which are not stated.

No reply has been received from Dr. Loughridge, probably due to his being so far away, but the chairman knows that he thinks color should be given more emphasis.

Other members of the committee approved the report without comment.

GEORGE N. COFFEY,
Chairman.

REPORT OF COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

Your committee on standardization of field experiments report and recommend the adoption by the Society of the following resolutions:

Resolved,

1. That it is undesirable to publish the results of field experiments until they have been conducted three years or more on duplicated plots of not less than 1/40 acre, and preferably of 1/10 acre each.[1]

2. That the data of any field experiments be published so that there can be no confusion between the results actually obtained and the interpretation of the same.

C. V. Piper,
E. G. Montgomery,
W. H. Stevenson,
Committee.

REPORT OF THE COMMITTEE ON AGRONOMIC TERMINOLOGY.

Owing to the pressure of his secretarial and editorial labors, your chairman has been unable to give much attention to this work. However, the committee has continued to record an annotated list of the words and phrases of new or peculiar significance used by agronomists in America. It is now proposed to select from this list, from time to time, examples of such usages as commend themselves to the committee, and publish them in the Journal, with comment, in order that they may be discussed by the Society. To such words or phrases will be added any new terms which the committee may evolve to meet special needs as they arise.

Respectfully submitted,
C. R. Ball,
Chairman.

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[1] It will be noted in the minutes of the business session that on motion this resolution was amended by omitting the clause "of not less than 1/40 acre, and probably of 1/10 acre each," and was then adopted.—Secretary.

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INDEX.

PAGE.
Agronomic affairs . 45, 89, 133, 218, 260
Agronomy and botany 89
  Fundamental principles in ... 227
Aldehyde, salicylic, Field tests with a toxic soil constituent; 108
Alfalfa yields, Basing, on green weights 42
Articles, briefer 42, 122, 215

Bailey, C. H., paper on "The composition and quality of Mexican wheats and wheat flours" 57
  Brief article on "The composition and quality of wheat grown in mixtures with oats" 215
Barley, A statistical study of, at Dickinson (N. D.) Substation 171
  Winter, in Michigan 217
Books, new 224, 262
Botany, Agronomy and 89
Bouyoucos, Geo. J., paper on "Some observations on agricultural conditions in Germany, France and England" 139
Briefer articles 42, 122, 215

Call, L. E., paper on "The effect of different methods of preparing a seed bed for winter wheat upon yield, soil moisture, and nitrates" (Figs. 24–25, Pls. V–VI) .. 249
Cereals, Sterile florets in wheat and other 24
Clark, J. Allen, paper on "A statistical study of barley at Dickinson (N. D.) Substation" (Figs. 12–18) 171
Committees, Reports of the 283
  Agronomic Terminology 289
  Executive 283
  Soil Classification and Mapping 284
  Standardization of Field Experiments 289
Community growing of crop varieties 31
Corn, A new method of growing. 84
Crop production, The theory of factors in 218
  varieties, Community growing of 31
Crops, Mutual influence of certain, in relation to nitrogen 204
Cunningham, C. C., paper on "A new method of growing corn" (Figs. 3–4) 84

Doctorates conferred in 1914 220

England, Some observations on agricultural conditions in Germany, France and 139
Engravings, Do members want their? 134
Events, coming 48, 96, 137, 226
Executive committee, Report of .. 283
Experimental agronomic work, Uniformity in 131
Experiments, Some applications of the method of least squares to agricultural 190
  on the plans of fertilizer 36
  standardization of field, Report of committee on 289
Extension, Expansion of agricultural 133

Factors, The theory of, in crop production 218
Farrell, F. D., brief article on "Basing alfalfa yields on green weights" 42

PAGE.
Fertilizer experiments, On the plans of 36
Florets, Sterile, in wheat and other cereals 24
Flours, wheat, The composition and quality of Mexican wheats and 57
Forage yields, Moisture as a factor of error in determining 113
France and England, Some observations on agricultural conditions in Germany,.... 139
Fry, William H., paper on "Petrography of various soils derived from volcanic ejecta" 164
Funds collected by the secretary. 264

Germany, France and England, Some observations on agricultural conditions in 139
Giles, P. L., paper on "On the plans of fertilizer experiments" (Fig. 2) 36
Grantham, A. E., brief article on "The effect of rate of seeding on competition in wheat varieties" 124

Harris, Frank S., paper on "The effect of soil moisture, plant food and age on the ratio of tops to roots in plants .. 65
Hirst, C. H., see Stewart, Robert.

Index 291

Journal and Proceedings, Secretary's report on 275

Kellerman, Karl F., and Wright, R. Claude, paper on "Mutual influence of certain crops in relation to nitrogen" (Figs. 20–23) 204
Khankhoje, P. S., paper on "Some factors which influence the water requirements of plants" (Fig. 1) 1

PAGE.
Legumes, nonlegumes, and, Percentage of protein in, when grown alone and in association in field mixtures... 210
Love, H. H., paper on "Relation of yield of straw and grain in oats" (Figs. 5–11) 97

McCool, M. M., paper on "Some unusual soils that occur in Oregon" 159
McKee, Roland, paper on "Moisture as a factor of error in determining forage yields" (introduction by C. V. Piper) 113
Meeting, annual, Minutes of the.. 276
  Special, at Dallas, Texas 46
Meetings, Secretary's report on .. 265
Members, Address list of 266
Membership changes, 47, 90, 135, 225, 265
  Secretary's report on 265
Mexican wheats and wheat flours, The composition and quality of 57
Michigan, Winter barley in 217
Minutes of the annual meeting .. 276
Mixtures, field, Percentage of protein in nonlegumes and legumes when grown alone and in association in 210
  with oats, The composition and quality of wheat grown in 215

New year, A thought for the 45
Nitrates, The effect of different methods of preparing a seed bed for winter wheat upon yield, soil moisture and ... 249
"Nitre spots," The origin of the, in certain western soils.... 241
Nitrogen and organic matter in dry-farm soils 49
  Mutual influence of certain crops in relation to 204
Nonlegumes and legumes, Percentages of protein in, when

PAGE.
grown alone and in association in field mixtures...... 210
North Dakota, A statistical study of barley at Dickinson substation 171
Notes and news 91, 136, 221, 261

Oakley, R. A., see Westgate, J. M.
Oats for the Southern States, Notes on 118
  Relation of yield of straw and grain in 97
  The composition and quality of wheat grown in mixtures with 215
Olmstead, L. B., paper on "Some applications of the method of least squares to agricultural experiments" (Fig. 19) 190
Oregon, Some unusual soils that occur in 159
Organic matter, Nitrogen and, in dry-farm soils 49

Passing, In 260
Peterson, William, see Stewart, Robert.
Petrography of various soils derived from volcanic ejecta. 164
Piper, C. V., paper on "Fundamental principles in agronomy" (presidential address) 227
  paper on "The name of the soy bean: a chapter in its botanical history 75
Plants, Some factors which influence the water requirements of 1
  The effect of soil moisture, plant food and age on the ratio of tops to roots in.... 65
Plats, Check, a source of error in varietal tests 128
  Use and management of, in soil fertility investigations 122
Presidential address 227
Principles, Fundamental, in agronomy 227

PAGE.
Proceedings, Journal and, secretary's report on 275
Production, crop, The theory of factors in 218
Protein, Percentage of, in nonlegumes and legumes when grown alone and in association in field mixtures ... 210

Report of the secretary for 1914.. 264
  seven-year summary. 279
  Treasurer 282
Reports of committees, see committees 283
Roots in plants, The effect of soil moisture, plant food and age on the ratio of tops to. 65

Salmon, Cecil, brief article on "Check plats a source of error in varietal tests" 128
  paper on "Sterile florets in wheat and other cereals" (Pls. I–II)................ 24
Schreiner, Oswald, and Skinner, J. J., paper on "Field tests with a toxic soil constituent; salicylic aldehyde" (Pls. III–IV) 108
Scofield, C. S., paper on "Community growing of crop varieties" 31
Secretary, Report of the, for 1914 264
  seven-year summary. 278
Sections, local 48, 96, 138, 190
Seed bed, The effect of different methods of preparing a, for winter wheat upon yield, soil moisture, and nitrates. 249
Seeding, The effect of rate of, on competition in wheat varieties 124
Skinner, J. J., see Schreiner, Oswald.
Soil classification and mapping, Report of committee on ... 284
  constituent; salicylic aldehyde, Field tests with a toxic 108

PAGE.
Fertility investigations, Use and management of check plats in 122
Soils, certain western, The origin of the "nitre spots" in 241
Nitrogen and organic matter in dry-farm 49
Petrography of various, derived from volcanic ejecta. 164
Some unusual, that occur in Oregon 159
Soy bean, The name of the, a chapter in its botanical history 75
Spragg, Frank A., brief article on "Winter barley in Michigan" 217
Squares, least, Some applications of the method of, to agricultural experiments 190
Standardization of field experiments, Report of committee on 289
Stewart, Robert, and Hirst, C. H., paper on "Nitrogen and organic matter in dry-farm soils" 49
and Peterson, William, paper on "The origin of the 'nitre spots' in certain western soils" 241
Summary, Seven-year, Report of the secretary 278
Terminology, agronomic, Report of committee on 289

Tests, Check plats a source of error in varietal 128
Theory of factors in crop production, The 218
Treasurer, Report of the 282
Tucker, George M., brief article on "Uniformity in experimental agronomic work"... 131

PAGE
Varietal tests, Check plats a source of error in 128

Warburton, C. W., paper on "Notes on oats for the Southern States" 118
Water requirements of plants, Some factors which influence the 1
Westgate, J. M., and Oakley, R. A., paper on "Percentage of protein in nonlegumes and legumes when grown alone and in association in field mixtures" 210
Wheat and other cereals, Sterile florets in 24
The composition and quality of, grown in mixtures with oats 215
varieties, The effect of rate of seeding on competition in.. 124
winter, The effect of different methods of preparing a seed bed for, upon yield, soil moisture, and nitrates 249
Wiancko, A. T., brief article on "Use and management of check plats in soil fertility investigations" 122
Work, Uniformity in experimental agronomic 131
Wright, R. Claude, see Kellerman, Karl F.

Yield of straw and grain in oats, Relation of 97
soil moisture, and nitrates, The effect of different methods of preparing a seed bed for winter wheat upon. 249
Yields, alfalfa, Basing on green weights 42
Moisture as a factor of error in determining forage 113

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CONTENTS

Fundamental Principles in Agronomy. (Presidential Address.) C. V. Piper.. 227
The Origin of the " Nitre Spots " in Certain Western Soils. Robert Stewart.. 241
The Effect of Different Methods of Preparing a Seed Bed for Winter Wheat upon Yield Soil Moisture, and Nitrates. (Figs. 24–25, Pls. V–VI.) L. E. Call 249

Agronomic Affairs.

In Passing 260
Notes and News 261
New Books 262
Report of the Secretary for 1914 (Funds Collected,—Meetings,—Membership,—Address List of Members,—Journal and Proceedings, Minutes of the Annual Meeting,—Seven-year Summary) 264
Report of the Treasurer 282
Reports of Committees (Executive,—Soil Classification and Mapping,—Standardization of Field Experiments,—Agronomic Terminology) 283
Index 291

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